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Super Capacitor based Battery Power Management for Hybrid Vehicles

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***Abstract*:- This paper presents super capacitor and battery association methodology for Hybrid vehicle. This has currently lead-acid batteries with a rated voltage of 540 V, two motors each one coupled with one alternator. The alternators are feeding a DC-bus by rectifiers. The main objective is to study the management of the energy provided by two super capacitor packs. Each super capacitor module is made of 108 cells with a maximum voltage of 270V. This is carried out for studies and innovating tests for the Hybrid Vehicle applications. The multi boost and multi full bridge converter are studied to define the best power management scheme. A good power management strategy by using multi boost and the multi full bridge converter . The experimental and simulation results of the two converter are presented.**

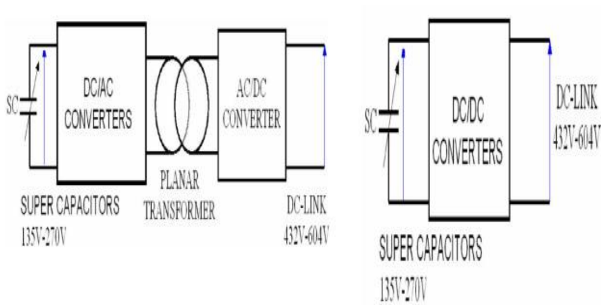
Keywords:- «Supercapacitors», «Boost converter», «Full bridge converter», «Power management»

1. 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 presenting a promising solution.

Supercapacitors are 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. Hybridization using batteries and super capacitors [1] for transport applications is needed when energy and power management are requried during the transient sates and steady states. 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



(a) First solution (b) Second Solution

Figure1: Converter topologies for ECCE Hybrid Vehicle

2. DC/DC CONVERTERS TOPOLOGIES AND MODELLING

2.1. Multi boost and Multi full bridge converters modelling

- Figure 2a shows the multi boost converter topology. The general model for this topology [2] is given by equation (1); where (α1) and (n) define respectively the duty cycle and parallel input converter number.

$$L_n \cdot \frac{d}{dt}(I_{sc_n}) = V_{sc_n} - \alpha_1 \cdot V_{bus1}$$

$$n = 1,2,\cdots, N_p$$

$$I_L \cdot V_{bus1} = P_{bus1} + P_{bus2} + \cdots + P_{busn}$$

$$\lambda \cdot \frac{d}{dt}(I_{bat}) = V_{bat} - V_{bus1}$$

$$I_{ch} = I_{bat} + k \cdot I_L$$

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The voltage drops in the L_n and λ inductances are given by equation (2).

$$v_{Ln} = L_n \cdot \frac{d}{dt}(I_{scn})$$

$$v_{\lambda} = \lambda \cdot \frac{d}{dt}(I_{bat})$$

(1)

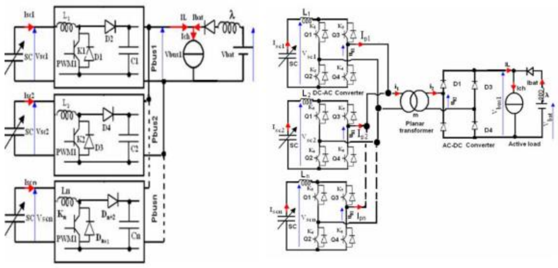

Figure-2: Multi boost Converter topology, Multi full bridge converter topology

(2)

The converter average model has a nonlinear behavior because of crosses between α1control variable and V_{bus1} parameter. The V_{bus1}, V_{sc1}, V_{sc2}, V_{scn} , I_{ch} and V_{bat} variables can to disturb the control, they must be measured and used in the estimate of the control law to ensure a dynamics of control [3]. The multi boost converter [4] topology control law which results from the boost converter modeling is presented by α1 duty cycle (3); where N_p = max(n) is the maximum number of parallel converters.

$$\alpha_1 = 1 - \frac{1}{N_p} ? \frac{(V_{sc1} + V_{sc2} + ??? + V_{scn}) - (V_{L1} + V_{L2} + ??? + V_{Ln})}{V_{bat} - V_{\lambda}} \quad (3)$$

The multi boost converter control strategy is presented in Fig.3 (a). It ensures the super capacitor modules discharge with variable current. The super capacitors reference current (I_{scref}) is obtained starting from the power management between batteries and hybrid vehicle DC -link. This control strategy includes the super capacitors and batteries current control loops. PWM1 signal ensures the multi boost converters control during super capacitor modules discharge. These modules being identical, the energy management between the modules and the hybrid vehicle DC-link enables to write the super capacitors current references (4).

$$I_{sc} = I_{sc1} + I_{sc2} + \cdots + I_{scn}$$

$$I_{screfn} = \frac{1}{N_p} \cdot \frac{V_{bus1}}{\eta \cdot V_{scn}} \cdot (I_{ch} - I_{batref})$$

$$I_{scref} = I_{scref1} + I_{scref2} + \cdots + I_{screfn}$$

To simplify the super capacitors current references estimation, the multi boost converter efficiency (η) was fixed at 85%.

- The multi full bridge converter [5] control strategy proposed in this paper consists to establish the full bridge converters standardized voltage [6]. The control law which result from the multi full bridge converter modeling is presented by equation(5), where (m) defines the transformer turns ratio.

$$U_{mod} \approx \frac{1}{m} \cdot \frac{V_{bat} - V_{\lambda}}{\eta \cdot V_{scn}}$$

$$V_{scn} = \frac{V_{sc1} + V_{sc2} + \cdots + V_{scn}}{N_p}$$

This standardized voltage is compared with two triangular carrier waves of amplitude V_{max} = 1V with a switching frequency of 20 kHz. The inverter control strategy is presented in Fig. 3(b); where Q_1, Q_2, Q_3 and Q_4 are the control signals applied to K_1, K_2, K_3 and K_4 switches. The simulations and experimental parameters are presented in table below.

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(a) Multi boost control

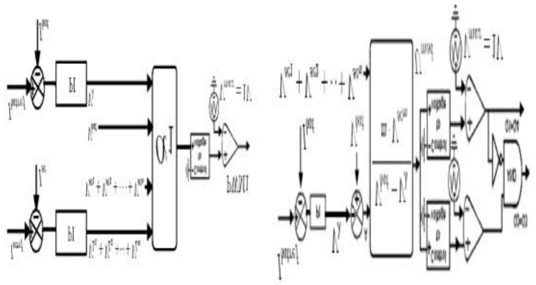

Figure 3. Multi boost and Multi full bridge converters control strategy

3. DESIGN

During the super capacitors discharge, the batteries current reference (I_{batref}) 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 (I_{ch}) was fixed at 53A .

Simulation Design Parameters
Battery:Nickel-Metal-Hydride,(Nominal, Rated)=(1.2*30,1.5*30)V,100%charge
Super capacitor : Capacitance:6800e-6
Active Load : 45V
IGBT/Diode:(Internal,Snubber)=(1e-3,1e5)Ohm, Snubber Capacitance:inf

*All the results are plotted with respect to time.

3.1. Boost converters simulation and experimental results

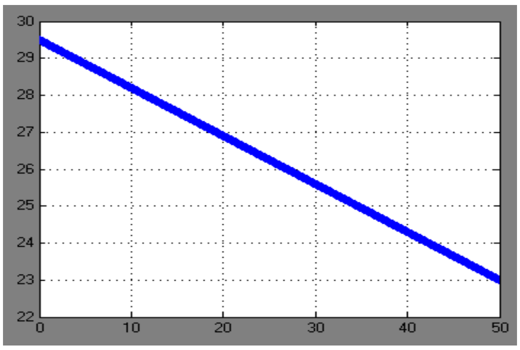

Figure-4. Super capacitor -module voltage results

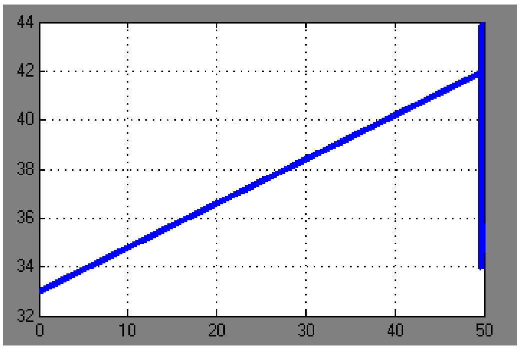

Figure 5. Super capacitor- modules current results

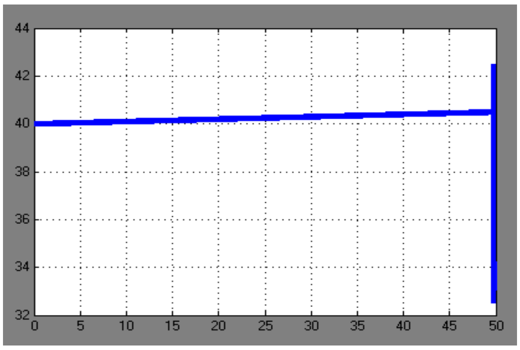

Figure-6: DC-link Load current

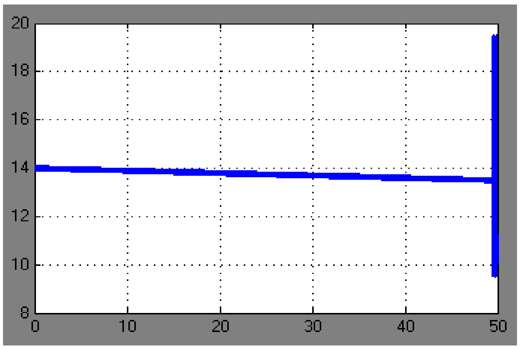

Figure 7. DC-Battery current

3.2. Full bridge converters experimental results

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.

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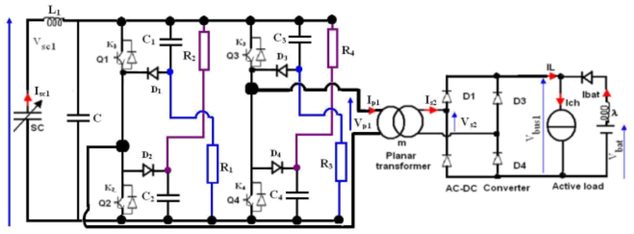

Figure-8:Full bridge converter with chopping devices

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 (C) 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 minimize 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 I and the principle of such circuits [8] is given in Fig. 8.

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
Vbus1	60V-43V	DC-link voltage
C	6800 µF	Super capacitors voltage smoothing capacitor
L_1	50µH	Super capacitors currents smoothing inductance

TABLE I: FULL BRIDGE EXPERIMENTAL PARAMETERS

During switching off of the semiconductors, the corresponding current stored in wiring inductances circulates in the following meshes C_1, D_1 ; C_2, D_2; C_3, D_3 and C_4 , D_4 which limits the voltages applied to the switches. When electrical energy is fully transferred in C1, C2, C_3 and C_4 capacitors, the current becomes null and the meshes become closed. The C_1, C_2, C_3 and C_4 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 R_1, R_2, R_3 and R_4 resistances. R_1, R_2, R_3 and R_4 resistances are identical and C_1, C_2, C_3 and C_4 capacitors are also identical.

Full bridge converter simulation results for $N_p = 2$:

The simulation has been made for $N_p = 2$ [7] . The maximum and minimum voltages of the super capacitor modules are respectively fixed at 270V and 135V. The hybrid vehicle requested current (I_{ch}) is respectively fixed at 100A from 0 to 0.5s, 400A from 0.5s to 18s and 100A from 18s to
20s. Battery reference current (I_{bat}) is fixed at 100A independently of the hybrid vehicle power request. Super capacitor module voltage (V_{sc}) presented in Fig.9 (a) are identical. The currents amplitude (I_{sc}) presented in Fig.9 (b) are also identical. Control enables to maintain the battery current (I_{bat}) at 100A; but around 0.5s and 18s the battery current control loop has not enough time to react . The important power of the transient states is ensured by the super capacitors module(I_L) Fig. 10(b). Simulation parameters are presented in TABLE II.

Symbol	value	Name
λ	25µH	Battery current smoothing inductance
m	3	Planar transformer turns ratio
Vbus1	604V-432V	DC-link voltage
$L_1 = L_2$	50µH	Super capacitors currents smoothing inductances

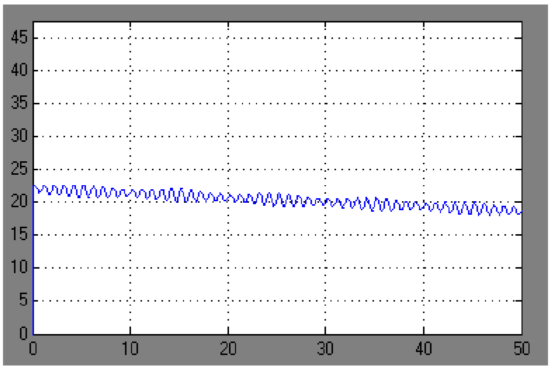

Figure-9: (a): Super capacitor modules voltages

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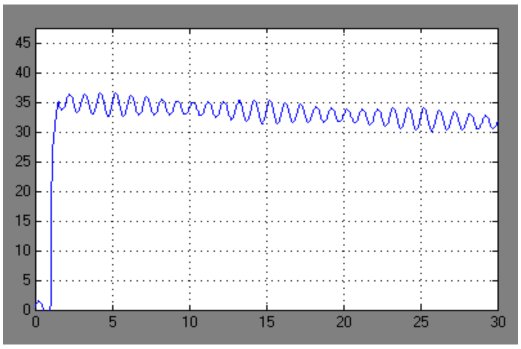

, (b): Super capacitor modules currents

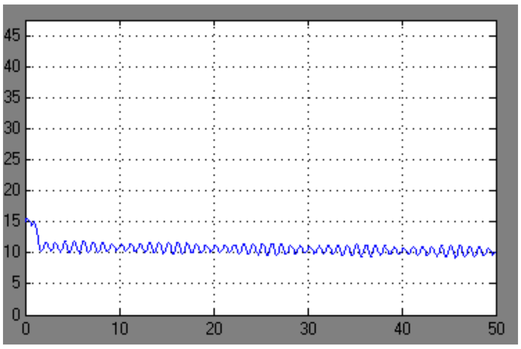

Figure-10: DC-link Load current

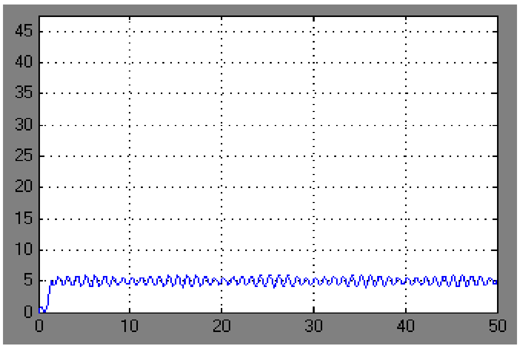

Figure-11: Battery current

4. CONCLUSION

In this paper, multi boost and multi full bridge converter topologies and their control strategies for batteries and super capacitors coupling in the hybrid vehicle applications were proposed. The system control is ensured by PIC18F4431 microcontroller type which includes 9 analog inputs and 8 PWM outputs.

For low voltage and high current applications such as super capacitors, the full-bridge converter seems to be less interesting because of its higher cost (many silicon and passive components), and a lower efficiency.

For reasons of simplicity and cost, the multi boost converter is the most suitable topology regarding the multi full bridge converter topology. It enables a good power management in hybrid vehicle.

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REFERENCES

[1] J.M Timmermans, P. Zadora, J. Cheng, Y. Van Mierlo, and Ph. Lataire. Modelling and design of super capacitors as peak power unit for hybrid electric vehicles. Vehicle Power and Propulsion, IEEE Conference, 7-9 September, page 8pp, 2005.

[2] Huang jen Chiu, Hsiu Ming Li-Wei Lin, and Ming-Hsiang Tseng. A multiple- input dc/dc converter for renewable energy systems. ICIT2005, IEEE, 14-17 December, pages 1304–1308, 2005.

[3] M.B. Camara, H. Gualous, F. Gustin, and A. Berthon. Control strategy of hybrid sources for transport applications using supercapacitors and batteries. IPEMC2006, 13-16 August, Shanghai, P.R.CHINA, 1:1–5, 2006.

[4] L. Solero, A. Lidozzi, and J.A. Pomilo. Design of multiple-input power converter for hybrid vehicles. IEEE transactions on power electronics, 20, Issue 5, 2005.

[5] Xin KONG and A. KHA. Analysis and implementation of a high efficiency, interleaved current-fed full bridge converter for fuel cell system. IEEE, 28-01 Nov, 1:474–479, 2005.

[6] M.B. Camara, F. Gustin, H. Gualous and A. Berthon. Studies and realization of the buck-boost and full bridge converters with multi sources system for the hybrid vehicle applications. Second European Symposium on Super capacitors and Applications, ESSCAP2006, Lausanne, Switzerland,2-3 November, 2006.

[7] Huang-Jen Chiu, Hsiu-Ming, Li-Wei Lin, Ming-Hsiang Tseng. A Multiple-Input DC/DC Converter for Renewable Energy Systems, Industrial Technology, ICIT2005, IEEE international Conference, 14-17 December 2005, Pages:1304-1308

[8] LOUNIS Zohra. APPOTS DES TECHNIQUES DE CABLAGES LAMINAIRES DANS UN ONDULEUR A IGBT DE MOYENNE PUISSANCE. PhD thesis, Institut National Polytechnique de Lorraine, 2000.

[9] Seong-Jeub Jeon, Gyu-Hyeong Cho. A Zero-Voltage and Zero-Current Switching Full Bridge DC-DC Converter With Transformer Isolation, IEEE Transactions on power Electronics, Vol.16, No.5, September 2001, Pages:573-580

[10] Yungtaek Jabg, Milan M.Jovanovic, Yu-Ming Chang. A New ZVS-PWM Full-Bridge Converter, IEEE Transactions on power Electronics, Vol.18, No.5, September 2003, Pages:1122-1129

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