International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

A Novel Design of Hybrid Energy Storage System for Electric Vehicles

Sonal V. Sonawane[1], Sushant Sananse[2]

PG Student, Department of Electrical Engineering, KCE's College of Engineering and Information Technology, Jalgaon, India[1]

Associate Professor, Department of Electrical Engineering, KCE's College of Engineering and Information Technology, Jalgaon, India[2]

ABSTRACT: Nowadays, the entire economic, social and political life of a modern country depends upon an efficient system of Transportation. In such case, hydrocarbon powered vehicles i.e. IC engines are used mostly in vehicles for transportation. But, the main drawback is the extinction of Fossil fuel (Hydrocarbon). To overcome this problem Electric Vehicle (EV) was discovered. In order to provide long distance endurance and ensure the minimization of a cost function for electric vehicles, a new hybrid energy storage system for electric vehicle is designed in this paper. For the hybrid energy storage system, the paper proposes an optimal control algorithm designed using a Li-ion battery power dynamic limitation rule-based control based on the SOC of the super-capacitor. At the same time, the magnetic integration technology adding a second-order Bessel low-pass filter is introduced to DC-DC converters of electric vehicles. As a result, the size of battery is reduced, and the power quality of the hybrid energy storage system is optimized. Finally, the effectiveness of the proposed method is validated by simulation and experiment.

KEYWORDS: Hybrid energy storage system, integrated magnetic structure, electric vehicles, DC-DC Converter, Power Dynamic Limitation.

I.INTRODUCTION

Nowadays new paradigms are emerging in rapid manner and the field of transport is looking for an alternative fuel which will not cause any environmental hazards to nature. According to the recent survey released by ministry of road and transport there are more than 250 million vehicles in India. All these vehicles contain mechanical powered IC engine and use fossil fuels for their operation. Because of these IC engines nearly 90% of the environment gets polluted drastically and to achieve a correct replacement to these engines the car manufacturers are shifting their attention towards the EV. Some of the major players have announced their production of EV. In recent times the EV are manufactured with the help of the DC motors which leads to losses and lower efficiency.

Due to the pollution caused by fossil fuel, new energy sources have been continuously developed. Nowadays, embedded energy storage systems in current generation electric vehicles are mostly based on the Li-ion batteries which, with high energy density, can provide long distance endurance for electric vehicles. While compared to the super capacitor, the response of Li-ion batteries is slower than that of super capacitors. Therefore, in order to make electric vehicles comparable to fuel vehicles with regards to fast transient acceleration, energy, and long-distance endurance, a hybrid energy storage system(HESS) consisting of Li-ion batteries and super-capacitors is applied to electric vehicles. For the development of electric vehicles, optimizing the energy storage device is critical, and it is necessary to consider increasing the capacity of the battery, while reducing the size and weight of the battery to increase the charging rate.

DC-DC converters which play an important role in hybrid energy storage system have been developed rapidly over the years. Through a series of innovations, a variety of DC-DC converters are proposed. A new zero Voltage Switch (ZVS) bidirectional DC-DC converter is proposed in , which has good controllability to improve conversion efficiency, but is not suitable for electric vehicles due to the complex control and higher cost. It has been shown an isolated bi-directional DC-DC converter with complex structure is able to convert a large power transmission. A new zero-ripple switching DC-to-DC converter with the integrated magnetic technologies is first proposed by S.Cuk, and the application is very successful. Isolated interleaved DC/DC converter introduces the concept of three-winding coupled inductors, but it is more suitable for power transmission.

II.TOPOLOGY OF HYBRID ENERGY STORAGE SYSTEM

Fig.1 is a proposed hybrid energy storage system

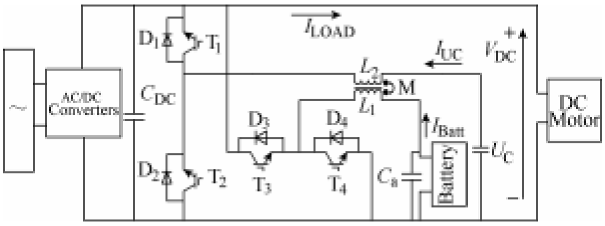


Fig.1 Topology of the hybrid energy storage system

composed of DC/DC converter, super capacitors and the Li-ion battery. DC/DC converters consist of four IGBT switches T1~T4 and its corresponding diode (added battery) tube D1~D4, and an integrated magnetic structure —— self inductance L1 、 L2 and mutual inductance M, which share a core inductors. The battery pack provides power to the smooth DC motor. The super capacitor deals with the instantaneous state of peak power supply. The power management system of electric vehicles determines the electrical energy flow according to the load demand. The converter has five main operating modes (mode due to the additional battery pack change). Table 1 shows the specific operation mode of hybrid energy storage system corresponding energy flows and operating mode DC-DC converter.

III.DESIGN OF THE DC/DC CONVERTER WITH INTEGRATED MAGNETIC STRUCTURE:

Magnetic elements such as inductors, are the main components of energy conversion, filtering, electrical isolation and energy storage. The size of the magnetic element is a major factor in determining the size and weight of the converter. To achieve the integration of magnetic elements, an E-type magnetic core is used in this paper. Herein, a coupling inductance (L1 and L2) is used. As shown in **Fig.2,** L2 as the output filter inductor, L1 as the external inductance, and Ca as additional capacitance.

Table 1 The operation mode of hybrid energy storage

Working mode	**Power source**	**Power flow**	**Operation mode**
Parking charging mode	Ac power	Battery and super capacitor	Buck
Constant speed mode	Battery	DC	Boost
Acceleration mode	Super-capacitor	DC motor	Boost
Braking mode	Braking energy	Battery and super capacitor	Buck
Super-capacitor charging mode	Battery	Super capacitor and DC motor	Boost or buck

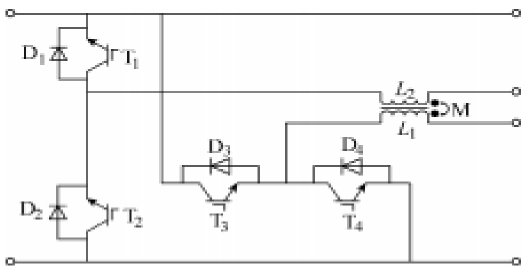
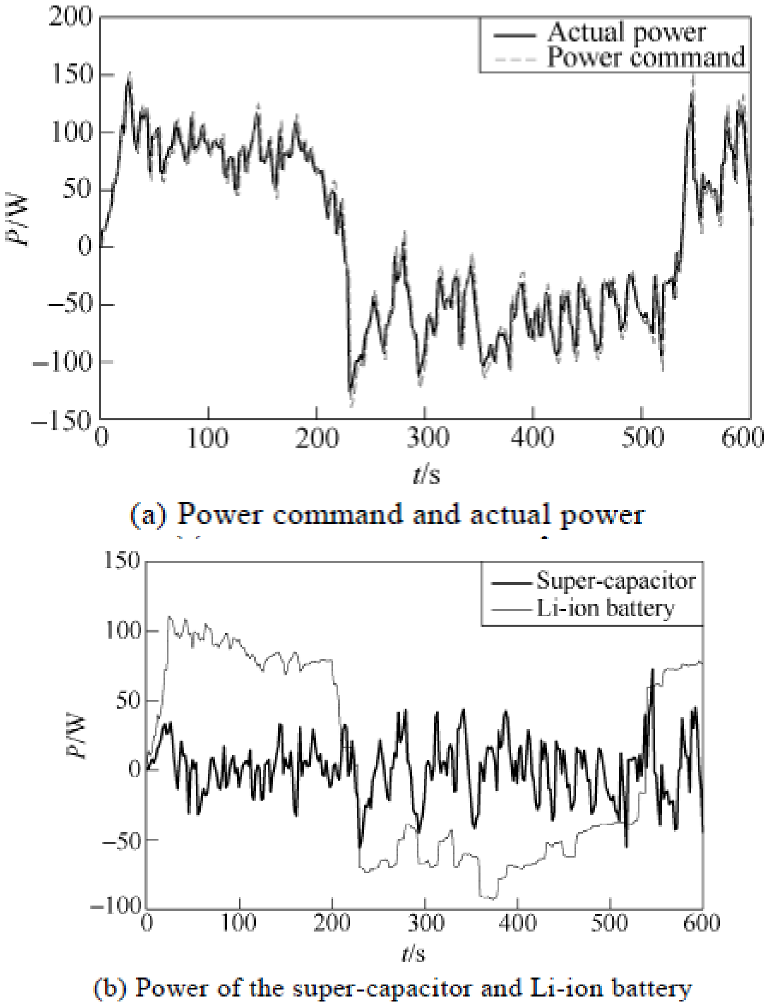


Fig.2 Topology of DC/DC converter with integrated magnetic structure

the voltage of Ca is equal to the output voltage of L2 and L1 without regard to the capacitor voltage ripple. The DC/DC converter of Fig.1 consists of 4 IGBT switches (T1~T4) and 4 diodes (D1~D4). As a boost converter, there are two operational modes (consisting of L1, T4, D4 or L2, T2, D1); and as a buck converter, there also are three operational modes (consisting of L1, T3, D4 or L2, T1, D2). It can be seen from Table 2, a comparison of two structures of DC/DC converter is illustrates that the volume and weight of the DC/DC converter with integrated magnetic structure are reduced. In the electric vehicle, the application of the DC/DC converter with integrated magnetic structure can reduce the overall size and weight of the energy storage system. Moreover, integrated magnetic structure can reduce the output current ripple. In section 4, the effectiveness of the integrated magnetic structure is validated by simulation and experiment.

IV.SIMULATION

The simulation model of the proposed HESS applied to a typical car driving cycle is built on Matlab/Simulink to test the dynamic performance of the system.The parameters of simulation system are presented in The simulation of cars during the acceleration mode, constant speed mode, braking mode and parking charging mode are built on Matlab/Simulink, and the stability of the load side and load side voltage, battery,super capacitor current ripple are observed.



(a) Power command and actual power

(b) Power of the super-capacitor and Li-ion battery

Compared to the super-capacitor current, the battery current changes are smoother with no instantaneous sperturbations. The output current of the battery pack is smooth and has minimal ripple content, which extends the life of the battery pack and can reduce the loss due to current ripple caused by the DC motor. The supercapacitors are responsible for the high-frequency contents of the load, so a sudden change in its current is normal.At the same time, we can see that a small amount of fluctuation in the load voltage, which is caused by vehicle acceleration or braking, and the voltage can be quickly restored to 300V by the super-capacitor.

V.EXPERIMENT

Finally, the paper makes an experiment to observe changes of the current of batteries and super-capacitors with step changes in the load. In order to fulfill the conditions in a laboratory environment, we built a small scale experiment and adopted boostcap PC2500 supercapacitor, which switches are HGTG30N60A4D IGBT, and the voltage and current senor are respectively LV 20-P and LA100-P. TMS320F2812 DSP is selected as a feedback and control systems. The

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

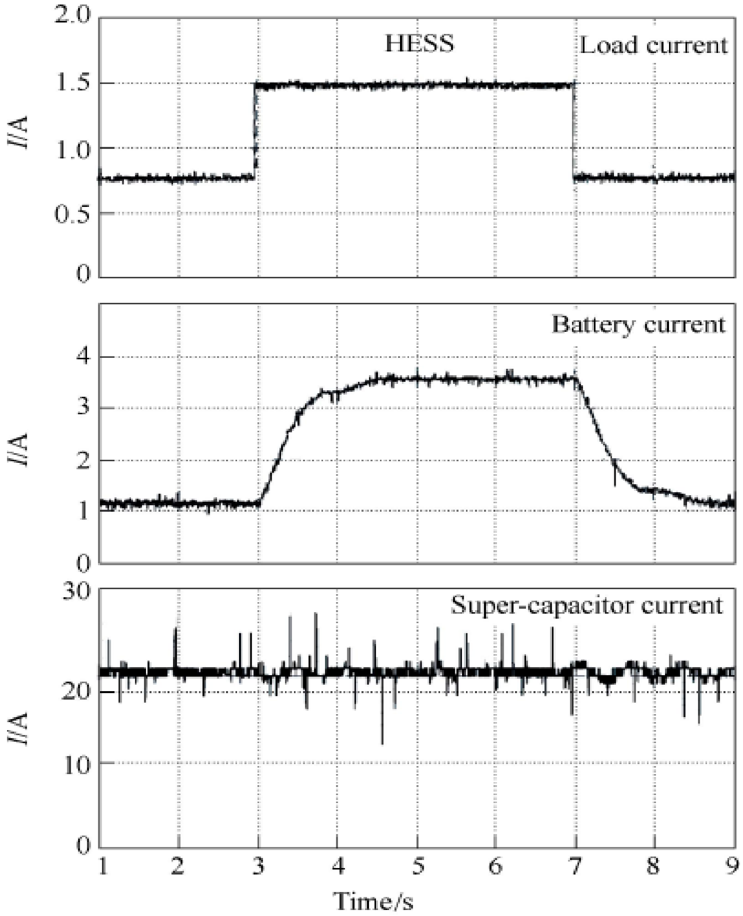
values of inductors *L*1, *L*2, and M were 2mH, 50H,50H.The actual values of these devices are shown in Table 6.Fig.9 shows the excellent ability of the proposed HESS in response to the acceleration and braking condition of electric cars. For energy storage systems with super-capacitors, when t =3 and the load step ups,the battery current is smooth and doing a slow controlled ramop, meanwhile, the super-capacitor repeatedly high-current discharge and DC voltage is stabilized at 20V which the overall volatility is less than 5%; When t =7 the load set down, super-capacitor recovered the braking energy, as we can see, the super-capacitor current is negative. For energy storage system without super-capacitors, the battery pack as a single storage is responsible for the set change in the load and has high fluctuation and ripple in current, which will reduce the life of battery. Compared with the proposed HESS, it is not suitable for electric vehicles.

VI.CONCLUSION

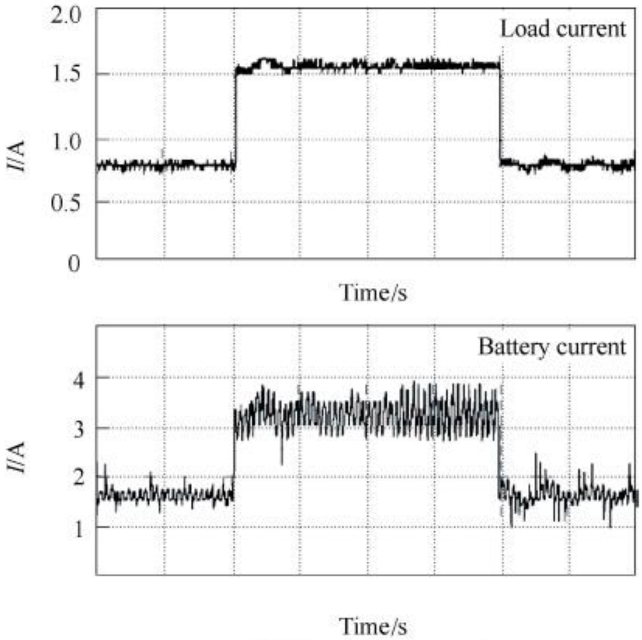
In this paper, a new hybrid energy storage system for electric vehicles is designed based on a Li-ion battery power dynamic limitation rule-based HESS energy management and a new bi-directional DC/DC converter The system is compared to traditional hybrid energy storage system, showing it has significant advantage of reduced volume and weight. Moreover, the ripple of output current is reduced and the life of battery is improved.

Experimental equipment and circuit parameters

Experimental data	
DC side voltage/V	*V*dc = 20
Battery/V	*V*batt= 12
Super Capacitor	the initial charge state 80% lead-acid battery 6 Maxwell Boostcap PC2500 series connection 450F, the initial state of charge 12V
Switching frequency/kHz	*f*s =20
Sampling time/□s	*T*st =20
DSP model	TI-TMS320F2812
***L*1, *L*2/□H**	1.938 mH, 54.5687
***M*/□H**	52.7866
Switch model	HGTG 30 N 60 A 4 D IGBT
Voltage sensor	*LV* 20-*P*
Current sensor	*LA* 100-*P*



(a) With super-capacitor



(b) Without super-capacitor

The system is compared to traditional hybrid energy storage system, showing it has significant advantage of reduced volume and weight. Moreover, the ripple of output current is reduced and the life of battery is improved.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.122|

||Volume 9, Issue 6, June 2020||

REFERENCES

1. N. R. Tummuru, M. K. Mishra, and S. Srinivas, "Dynamic energy management of renewable grid integrated hybrid energy storage system, " *IEEE Trans. Ind. Electron*., vol. 62, no. 12, pp. 7728-7737, Dec. 2015.
2. S. Cuk, R. D. Middlebrook,"A new optimum to pology switching DC-to-DC converter," In: *Proceedings of 8th IEEE Power Electronics Specialists Conference*, pp.160-179, 1977.
3. J. Shen, S. Dusmez, and A. Khaligh, "Optimization of sizing and battery cycle life in battery/ultracapacitor hybrid energy storage systems for electric vehicle applications," *IEEE Trans. Ind. Informat*., vol. 10, no. 4, pp. 2112-2121, Nov. 2014.
4. S. K. Kollimalla, M. K Mishra , and N. L. Narasamma, "Design and analysis of novel control strategy for battery and super capacitor storage system, "*IEEE Trans. Sustain. Energy*, vol. 5, no. 4, pp. 1137-1144, Oct. 2014
5. K. Jaber, B. Ben Saleh, A. Fakhfakh, R. Neji, "Modeling and Simulation of electrical vehicle in VHDLAMS" 16th IEEE International Conference on Electronics, Circuits and Systems, ICECS 2009, pp. 908-911, ISBN 978-1-4244-5090-9, Dec 2009.