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DESIGN AND IMPLEMENTATION OF HYBRID STORAGE SYSTEM COMPOSED BY BATTERY AND ULTRACAPACITOR IN ELECTRIC VEHICLE

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Abstract—The main aim of our proposed system is to improve the efficiency and stability of used converters. The control of hybrid storage systems by batteries and ultra capacitors is proposed .A voltage and current controller is used to achieve the control. Simulation is performed in MATLAB SIMULATION and the results show the relevance of our approach. So in view of practical implementation, it will be required to improve the modeling of storage elements (battery, ultra capacitors, inductors and capacitors). Moreover, the performances of our hybrid energy storage system must be subjected to a variable load.

Keywords— Hybrid energy storage system, ultra capacitors, Battery, DC/DC converter.

I. INTRODUCTION

In this paper we have used the Hybrid system in Electric vehicle. As we know Electric source Hybridization is being studied in Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV) application. The main concept consists on reducing the size of the system, increasing life span and ensures robustness under load condition [1]. Now a day usage of Electric vehicle has been increased because of its economic and environmental benefits. Few years back, batteries were used as the storage system in EV's, but because of uneven loading profile of EV, the life time and the performance of batteries are reduced, because in the condition of peak and average load demand, batteries are only the one which supply the power [2].

The Battery-Ultra capacitor combination in Hybrid storage system is such a combination which can be used in Electric vehicle. By using Ultra capacitor batteries can be protected from high peak current, which not thoroughly but partially damage to the batteries [4]-[5]. Thus by this super capacitor may extend the lifetime of the battery. Li-ion battery is the mostly used as chargeable battery nowadays for many advantages, such as higher voltage level, higher energy density etc. Management of battery for battery packs composed of multiple numbers of cells is quite change from single cell application and thus the problem arises.

Super capacitor can be used in combination with the batteries in storage system of any Electric vehicle for the following:

1. To improve acceleration of vehicle;
2. To improve all over efficiency of a drive;
3. To reduce the cost of life cycle by extending the battery life;
4. To reduce capital cost.

Li-ion batteries are long life batteries used in portable consumer like calculator, iPods, and wrist watches. Cost and long term life cycle are the main concerns of Li-ion based Energy storage system. Performance of Li-ion battery storage solution ensures that any excess power generated by the PV system can be stored in the storage unit immediately. Li-ion battery gives you a complete freedom as consumer. You can switch on your household appliances whenever you want without having the worry. No need to be connected to an Electrical system which is preferable in some cases.

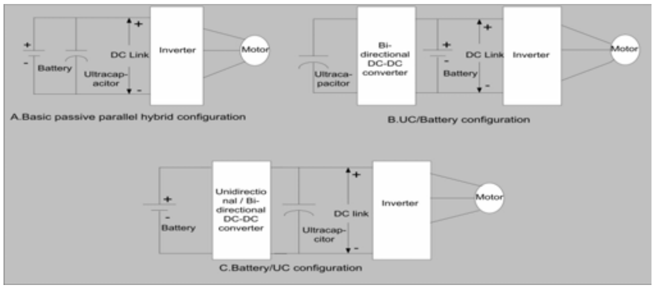

Fig.1 The Topology of Hybrid Energy System [3]

The main battery/Ultra capacitor Hybrid energy storage system topologies are shown in Figure 1.Various proposed architectures for Hybrid energy storage system using batteries and Ultra capacitors have been shown .In the Figure.1 (A).given above shows the basic Hybrid combination that of the power distribution between the batteries and the Ultra capacitor cannot be controlled. The power distribution between the batteries and Ultra capacitors can be controlled by

DC-DC converters. In Figure (B), there is a bi-directional DC-DC converter between the Ultra capacitor and battery bank. In these two topologies, voltage of the Ultra capacitor bank is not bound by that of the battery bank and that of DC bus. In Figure 1(B), battery bank is directly connected to the DC bus in parallel, so that the voltage of the DC bus is relatively more stable than that shown in Figure 1(C). In addition, the stored energy in the battery bank can be used more efficiently if it does not need to pass through a DC-DC converter. In Figure 1(C), the Ultra capacitor bank can be used more efficiently, but the voltage of the DC bus varies with the voltage of the Ultra capacitor bank over a huge range. Mostly, the minimum voltage of the Ultra capacitor bank is half of the maximum [3].

II. BATTERY AND ULTRACAPACITOR USED IN EV

Still till date batteries are the most extensive energy storage devices for storing electricity.

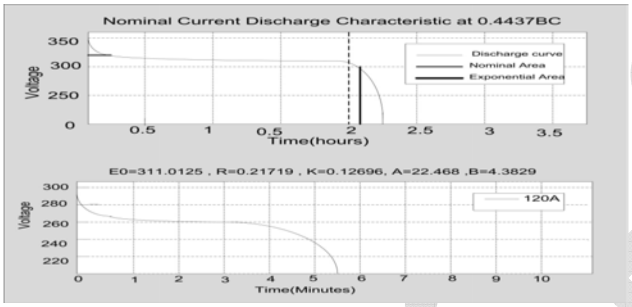

Fig.2. Discharge Characteristics of Li-ion Battery [MATLAB-R2012a] [2]

In battery the voltage curve is not actually constant. This is because the inner resistance is Linear during the discharge characteristics, but the losses are below 25% because of increase in internal resistance. Here we have used Li-ion battery, and the discharge characteristics curve of these batteries are shown in the figure 2.

Charging and Discharging of the batteries is a chemical reaction, but the Li-ion battery is claimed to be the exception .Scientists talk about flow of energies in and out of the battery as part of ion movement between anode and cathode. This claim has some merits but if the scientists were totally correct, then the battery would have survived forever. Scientists blame capacity fade on ions getting trapped, but as with all battery systems, internal corrosion and other degenerative effects still play a vital role. The Li-ion charger is a limiting voltage device that has similarities with to the lead acid system. The difference with the Li-ion battery lies in a higher voltage per cell; tighter voltage tolerances and the absences of trickle or float charge at full charge. Li-ion is a clean system and only accepts what it can absorb.

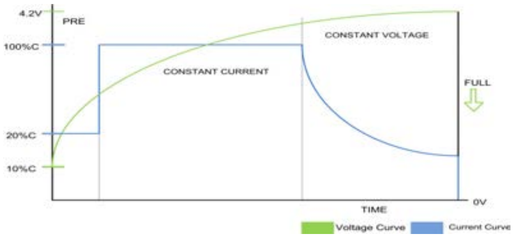

Fig.3.Charging Characteristics of Li-Ion Battery

Charge V/ cell	Capacity of cut-off voltage	Charging time	Capacity with full saturation
3.80	60%	120mm	~65%
3.90	70%	135mm	~75%
4.00	75%	150mm	~80%
4.10	80%	165mm	~90%
4.20	85%	180mm	100%

Table 1.Typical charged characteristics of Li-ion

Ultra-capacitor is a developing technology in the area of energy storage system. Improvement in the design technology and quality of material used in ultra-capacitor maximizes energy-storage capabilities of ultra-capacitors. Due to the activated layer of carbon on the electrodes, the surface area of the electrode is increased and the storing charge capacity of the ultra-capacitor is also increased tremendously. The voltage terminal of ultra-capacitors is limited, which is the main backlog. The output voltage of an ultra-capacitor ranges from 2.5 V to 3 V. But we can overcome this limit by making a module combination of series-parallel connection of cells. The efficiency of ultra-capacitor depends on the equivalent internal series resistance (ESR) of the capacitor. Charge-discharge efficiency of the ultra-capacitor is very high, and the energy loss through heat during each cycle is relatively small while the energy lost through heat in batteries is much larger, making heat removal more crucial and its extraction costs much higher. This is said that the cycle efficiency of batteries is around 80%, and the cycle efficiency of ultra-capacitor is around 95%.

Fig. 4 shows the Ragone Chart, that compares the different technologies of batteries and ultra-capacitors of specific power and energy density. From the graph it can be seen that, the energy density of the battery is somewhat high as compared to that of ultra-capacitor, while the power density of the ultra-capacitor is quite high as compared to of the battery. Though, a battery has the largest energy density, it is important to consider the availability of it. The advantage of ultra-capacitors is that, within a time less than 0.1 sec, energy can be taken from a capacitor at a very high rate. On the other side, a battery of the same size will not be able to supply the sufficient amount of energy in such a small period of time. Unlike batteries, ultra-capacitors can withstand a very large number of charge/discharge cycles without any change in quality.

It is obvious that, the batteries and ultra-capacitors work as complement to each other. So when batteries and ultra-capacitor works combine, uneven loading profile of the EV can also be handled very efficiently, without any change of the battery life.

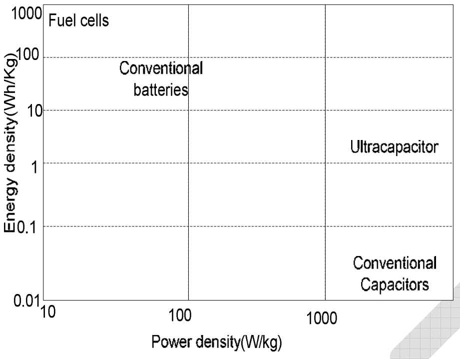

Fig.4. Ragone Chart [2]

III. BATTERY AND SUPERCAPACITOR HYBRIDIZATION

A. Hybridization Concept

High capacitance and high power density of an ultra-capacitors favors its possibility in Electric vehicle applications, the capacity of energy to limit which orders the need for a much higher energy supportable source, such as a battery bank. The main objective of integrating batteries and ultra-capacitors is to create an energy storage system with the high energy density and power density of a battery and ultra-capacitor. The main goal is to exploit the benefits of both the devices through ultra-capacitor hybridization of the two technologies in vehicular power system architecture. Here the primary energy source is connected to the battery and to the buffer system ultra-capacitor is connected .When ultra-capacitor works in blend with battery, peak power demand will be provided by the ultra-capacitor, while the average power demand will be complete by the battery. Thus there are no chances of sudden overloading on the battery hence the battery life and efficiency of whole energy storage system can be enlarged.

B. Purpose of Hybridization

The changes that may occur between chemically definite energy carriers, for example diesel, kinetic energy and gasoline are still providing the main bulk of force energy in a hybrid Electric Vehicle (HEV). The energy carrier provides the energy to the internal combustion engine (ICE). It is possible for the usage of hybridization in blend with other more environmental friendly energy carriers as well. The purpose to present the hybrid drivetrain is to reduce the fuel consumption (and improve efficiency) of the ICE. There are a number of dissimilar techniques and outlines those are used to utilize the hybridization of a vehicle and to enhance the energy efficiency of the storage system used in the EV.

1. Regenarative braking

While operating with an Electric vehicle, it is possible to renew some of the kinetic energy that the vehicle has acquired during acceleration. Conventionally, the braking energy is altered to heat by friction brakes, however in an Electric vehicle it is reasonable to transform the energy back to electricity and charge the battery instead. In an Electric vehicle, which does not have an ultra-capacitor connected, it is possible to redevelop about 20% of the brake energy (liable on power, vehicle and battery technology). The remaining power is degenerate in the friction predictable brakes. This is mostly due to the fact that the batteries can be spoiled if they handle to much brief power. If an ultra-capacitor is installed in the Electric vehicle this limit could be increased due to the high power capability of the ultra-capacitor.

2. Power Smoothing

The brief power appeal of a vehicle is resolute by a number of dissimilar factors, like the driving style, wind resistance and slope of the road. These factors make the temporary power request altering and the frequency of the modification in power demands could distract the fuel consumption for a normal non hybrid vehicle. An Electric Vehicle with a permanent magnet synchronous motor (PMSM) using energy storing unit acts as loss filter and supply the Drivetrain, with the additional power desired according to the uneven loading profile of the vehicle.

1V. Case study and Simulation Results

The projected Hybrid energy storage system is being used to expand the performance of a present power-split, heavy-duty in Hybrid Electric Vehicle. Based on the design objective of the Hybrid Electric vehicle parameters of the planned Hybrid energy storage system are calculated. To confirm the performance of the planned HESS and control strategy, a model of the HESS was produced in the MATLAB/Simulink simulation environment.

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A. Drivetrain Configuration of the HEV

The drivetrain outline of the power-split HEV is shown in Figure 5[7]. The drivetrain consists of two motor/generators (MGs), one internal combustion engine (ICE), the power-split transmission and one battery bank as the ESS. The two MGs and ESS are connected in parallel to the DC bus. The improvement in the presentation of the battery bank using the proposed HESS will be proven in the simulations.

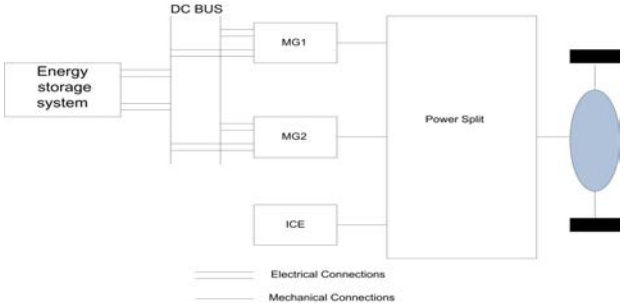

Figure 5 The drivetrain configuration of the HEV [3].

Figure 6 illustrates a part of the new data for the DC bus power of the present HEV. When the DC bus power is positive, the DC bus provides electrical energy to the energy storage system; when the power is negative, the DC bus draws electrical energy from the energy storage system. These experimental data are used for the DC bus power level in the simulation

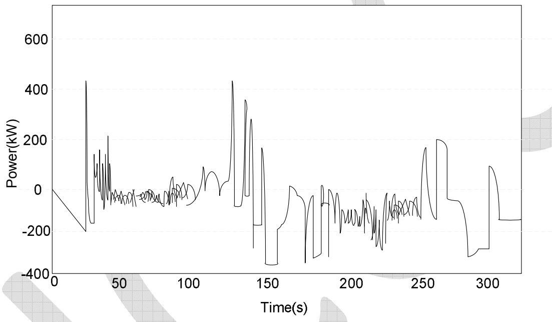

Figure 6 Experimental data for the DC bus power

B. Parameters of the proposed HESS

1. Design Objectives for the Proposed HESS

The objectives of designing the HEV are used to compute the parameters of the planned HESS in this division. When parameters of the HESS are computed, only the conditions in which electrical energy stored is being transferred must be considered. For this Hybrid electric vehicle, there are three operating modes in which electrical energy is transferred: the electric drive mode, the acceleration mode and the regenerative mode. In the electric drive mode, it is required that the Hybrid Electric vehicle drive 1 hour at a speed of 15 km/h using electrical energy only. In the regenerative mode, the design goal is to decelerate from 85 km/h to 0 km/h in 5 s. The design goal of the acceleration mode is to accelerate from 0 to 32 km/h in 7 s. The power and energy demands of these three operating modes were calculated in [3]-[6], and they are listed in Table 2.

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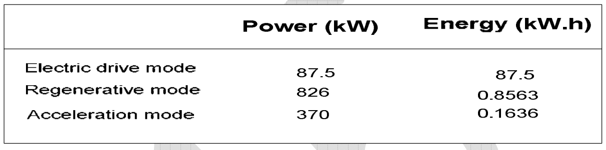


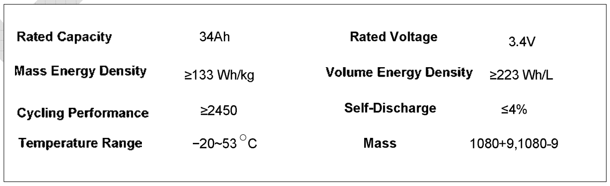
	Power (kW)	Energy (kW.h)
Electric drive mode	87.5	87.5
Regenerative mode	826	0.8563
Acceleration mode	370	0.1636

Table 2 Power and Energy requirement in Hybrid system [3]

The features batteries and the UCs are such that the battery bank, with its high energy density, is used to meet the maximum energy and power loads in the electric drive mode, and the UC bank, with its high power density, is used to match the high power levels in the regenerative and acceleration modes.

2. Battery Bank Parameters

The battery bank of the proposed HESS uses the batteries from the existing drivetrain. The main parameters of the battery cells are shown in Table 3.



Rated Capacity	34Ah	Rated Voltage	3.4V
Mass Energy Density	≥133 Wh/kg	Volume Energy Density	≥223 Wh/L
Cycling Performance	≥2450	Self-Discharge	≤4%
Temperature Range	−20~53 °C	Mass	1080+9,1080-9

Table 3 The parameters of the battery cell [3]

The calculated method for the parameters of the battery bank was presented in [6]. The results of these calculations are shown in Table 4.

Quantity in series	240
Quantity in parallel	7

Table 4 The calculate results of batter bank [3]

3. UC Bank Parameters

The UC bank in the prearranged HESS is used to tie the power levels in the regenerative mode and the acceleration mode. In addition, the energy capacity of the UC bank must be enough to tie the bus energy stages of these two modes.

(1) The quantity of cells in series in the UC bank

For the creation of the proposed HESS, the lesser voltage limit of the UC bank should be equal to the lower voltage limit of the battery bank. The series number of the UC bank is considered from equation (1).

$$n_{uc} \times V_{uc_{min}} = V_{ucbank\_min} = V_{battbank\_min} \qquad (1)$$

where n_{uc} is the quantity of cells in series in the UC bank, $V_{uc_{min}}$ is the minimum voltage of one UC, V_{ucbank_min} is the minimum voltage of the UC bank, and $V_{battbank\ min}$ is the minimum voltage of the battery bank.

The value of $V_{battbank\ min}$ was set to 420 V. If, $V_{uc_{min}}$ is set to 1/2 of the upper voltage limit of the UC cells. The upper voltage limit of the chosen UC cells is 2.7 V, so since the margin, $V_{uc_{min}}$ was set to 1.4 V. Then, n_{uc} can be calculated from Equation (1), which gives a value of 300.

(2) The capacity of one UC

The UC bank for the planned HESS should absorb the maximum retrieved energy for one application of the brakes and the given design objectives. The capacity of one UC can be calculated by using Equation (2):

$$\frac{1}{2} \times n_{uc} \times C \times (V_{uc\ max}^2 - V_{uc\ min}^2) + t \times P_{dc-dc} \geq E_{brake} \qquad (2)$$

where C is the capacity of one UC, is the upper voltage limit of one UC (2.7 V), is the E_{brake} maximum recovered energy of design objectives, t is the braking time (5 s according to the design objectives) and P_{dc-dc} is the power limit of the bi-directional DC-DC converter. The calculated results for one UC capacity for various power limits on the DC-DC converter are listed in Table 5. These values would be used to select the actual UC products.

DC-DC power limit (kW)	50	100	150	200	250
UC cell capacity (F)	3630	3316	3005	2691	2379

Table 5 The calculated results for one UC capacity for various DC-DC powers

C. Simulation Results

The proposed HESS model was built in the MATLAB /Simulink simulation environment; the Simulink model is shown in Figure 7. The model includes the UC bank, the battery bank, the DC bus, the bi-directional DC-DC converter, the control module, the switches S1 and S2 and the diodes D1 and D2.

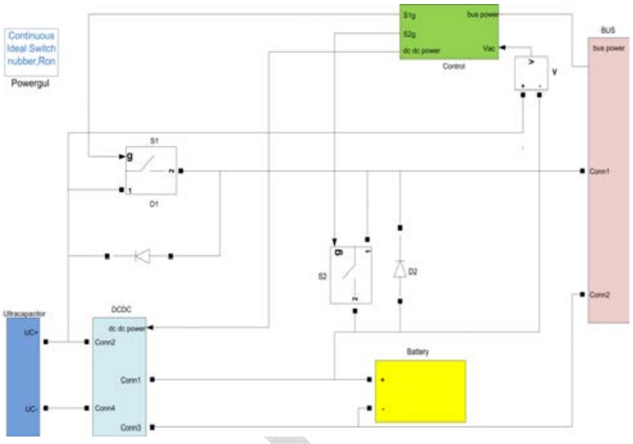
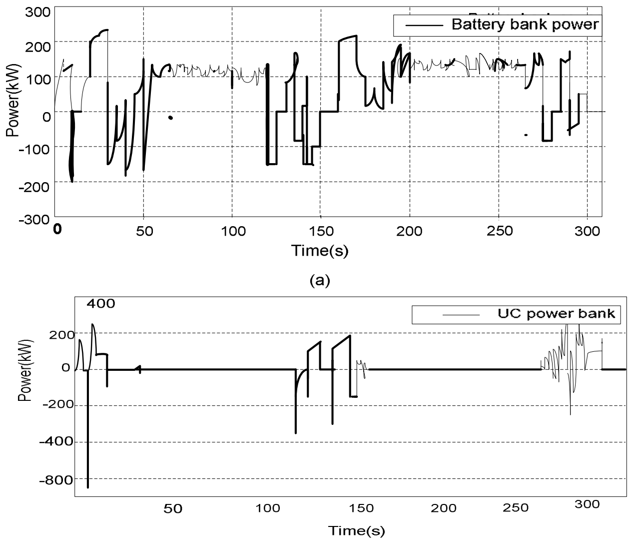


Figure 7 Simulation model in MATLAB/Simulink [3].

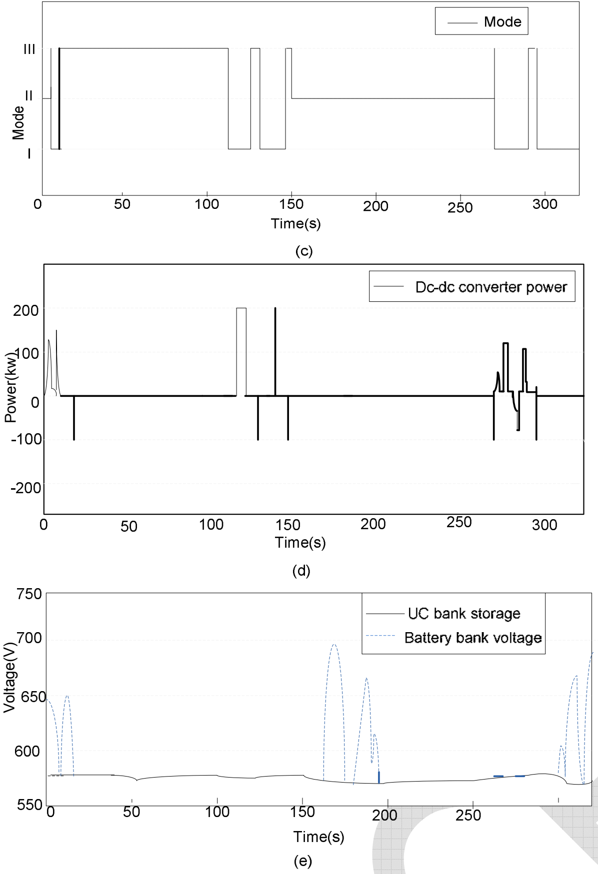
A set of simulation results are shown in Figures 6, the power limits of the bi-directional DC-DC converter is 150Kw.In the simulation given; the power limit of the battery is 250Kw. In the conventional configuration shown in Figure 1c, when the power limit of the battery bank is 250 kW, the power capacity of the bi-directional DC-DC converter must be at least 400 kW to accommodate the 650 kW peak (in the regenerative Mode) shown in Figure 5.

Figure 8.Simulation results with a 150kW power limit on the DC-DC converter: (a) battery bank power; (b) UC bank power; (c) mode; (d) bi-directional DC-DC converter power; (e) voltage of the battery bank and the UC bank [3].



(a)

(b)



V. CONCLUSION

The performance of an existing HEV was improved using the proposed HESS. Simulations of the proposed configuration and control strategy were performed in the MATLAB/Simulink simulation environment. A method for calculating the parameters of the proposed HESS was presented. The simulation results showed that with the calculated values of the parameters, the proposed HESS could satisfy the power and energy demands of DC bus with a lower capacity DC-DC converter than was required with the traditional HESS. Moreover, by different series-parallel connections in battery Hybrid and ultra-capacitor modules the efficiency and reliability of storage system can be proved.

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