ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.6, Pages : 207-212 (2013)

Special Issue of ICETEM 2013 - Held on 29-30 November, 2013 in Sree Visvesvaraya Institute of Technology and Science, Mahabubnagar – 204, AP, India

Ultracapacitor Hybrid Energy Storage System with a battery in Electric Vehicles

[1]Mallikarjun.P [2]M.Shiva Kumar [3]J.Rakesh Sharan

[1]M.Tech Student , Dept of EEE,SICET
[2]Professor & HOD , EEE , SICET
[3]Asst.Prof , EEE,SICET

ABSTRACT

The conventional HESS(hybrid energy storage systems) design uses a DC/DC converter to interface between the ultra capacitor and the battery DC link to satisfy the real time peak power demands. The proposed design uses a much smaller DC/DC converter which works as a controlled energy pump to maintain the voltage of the ultra-capacitor at a higher value than the battery voltage for city driving conditions. The battery provides power directly only when the ultra-capacitor voltage drops below the battery voltage. Therefore, a relatively constant load profile is created for the battery. Energy from the regenerative braking is not used directly, thus the battery is isolated from frequent charges which increases the life of the battery.

INTRODUCTION

Electric vehicles, hybrid electric vehicles, and plug- in hybrid electric vehicles (EVs, HEVs, and PHEVs) need Energy storage systems (ESS) in which batteries are most widely used as energy storage devices [1]-[5]. However, a battery based ESS has several challenges which requires additional solutions. Power density of the battery needs to be high enough to meet the peak power demand in battery based energy storage systems. Batteries of high power density are typically priced much higher than their lower power density counterparts. Increasing the size of battery is one of the typical solutions but this will increase the cost. Thermal management is carried for safe working of batteries to reach the desired power limits, to cool down the battery during high power load and to warm up the battery in cold temperatures. In addition, an issue concerning the life of the battery is the balancing of the cells in a battery system. Without the balancing system, the individual cell voltages tend to drift apart over a period of time. Then the capacity of the total pack decreases rapidly during operation, resulting in the failure of the total battery system and also with high rate charging and discharging of batteries [6],[7]. In addition to these issues, applications that require instantaneous power input and output typically find batteries suffering from frequent charge and discharge operations, which have an adverse effect on battery life. So these systems require an additional energy storage system or a buffer which is much more robust in handling surge current. The above listed problems can be solved by using hybrid energy storage systems (HESS). The HESS combines ultra capacitors (UC) and batteries to achieve a better overall performance. The ultra-capacitors have a high power density and low energy density compared to batteries. So this combination provides better performance in comparison to the use of either of them alone. Several configurations for HESS designs have been proposed, which range from simple to complex circuits. Based on the use of power electronic converters in the configurations, HESS can be classified into two types of passive or active. Conventional active methods use one or multiple full size DC/DC converters to interface the energy storage device to the DC-Iinle The full size refers to the fact that the DC/DC converter forms the sole path for the flow of energy in the device. In the conventional HESS designs, the battery pack is directly connected to the DC link while a half bridge converter is placed between the UC bank and the DC link. However, in order to utilize the power density advantage of the UC, the half bridge converter must match the power level of the Uc. But the half bridge converter costs more. Although this design solves the problem of the peak power demands, the battery still suffers from frequent charge and discharge operations. To solve all these problems a new HESS is proposed in this paper.

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of some of the popular DC-to-DC converter topologies.

HYBRID ENERGY STORAGE SYSTEMS

Both batteries and UCs are types of electrochemical devices. However operating principles of both these devices are different making their characteristics also different. The batteries have a relatively high energy density of 30-200WhlKg, which vary with power density. But the UC has high power density and low energy density. The life of UC is much higher than that of batteries and also UCs have higher low temperature performance compared to batteries. These characteristics allow for an optimal combination in order to achieve an improved overall performance.

A. Basic Passive Parallel

Passive paralleling is the simplest method in which battery is combined with UC bank without any power electronic converters/inverters in between [4]. Figure 1 shows the basic topology of the passive parallel method. In this method, since the two sources are always paralleled, V Bau = V uc = V oc. The UC essentially acts as a low pass filter.

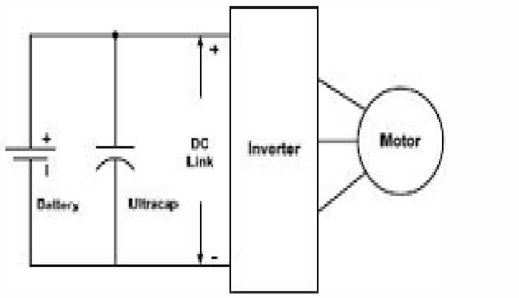

Figure 1. Basic passive parallel hybrid configuration.

Advantages of this method include ease of implementation, no requirements for control or expensive power electronic converters. The major drawback is that it cannot effectively utilize the UC stored energy.

B.Ultra-Capacitor/Battery Configuration

The ultra-capacitor/battery configuration [8] is most widely studied and researched HESS. Figure 2 shows the configuration of HESS. This method uses a bi-directional DC/DC converter which is used to interface the UC, the voltage of UC can be used in a wide range. But the size of the bi-directional converter needs to be higher in order to handle the power of the Uc. In addition, the nominal voltage of the UC bank can be lower. Since the battery is connected directly to the DC link, the DC link voltage cannot be varied.

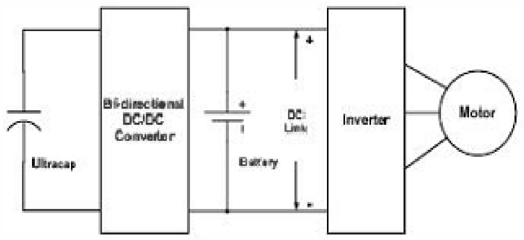

Figure 2. Ultra-capacitor / battery configuration.

C.Battery/Ultra-Capacitor Configuration

The battery and UC in the UC/battery configuration is interchanged to get the batterylUC configuration as shown in figure 3. Here the voltage of the battery can be maintained lower or higher than the UC voltage. The UC is connected to the DC link directly which works as a low pass filter. If the control strategy applied to this topology allows the DC link voltage to vary within a range so that the UC energy can be more effectively used.

D. Cascaded Configuration

In order to provide better operating range of the UC of the Battery/UC configuration, another bi-directional DC to DC converter was added between the UC bank and the DC link. This forms a cascaded converter topology as can be seen in Figure 4

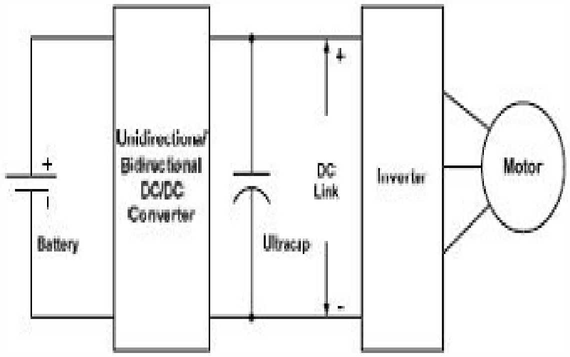

Figure 3. Battery/ultra-capacitor configuration.

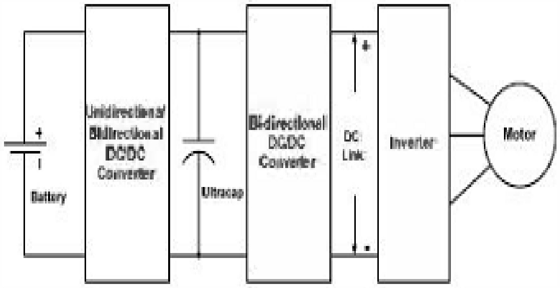

Figure 4. Cascaded configuration.

Both batteries and UCs are types of electrochemical devices. However operating principles of both these devices are different making their characteristics also different. The batteries have a relatively high energy density of 30-200WhlKg, which vary with power density. But the UC has high power density and low energy density. The life of UC is much higher than that of batteries and also UCs have higher low temperature performance compared to batteries. These characteristics allow for an optimal combination in order to achieve an improved overall performance.

E.Multipleconverter Configuration

The multiple converter method parallels the output of the two converters. Figure 5 shows the diagram of the multiple converter topologies. The outputs of the two converters are the same as the DC link voltage. In order to obtain less balancing problem the voltage of both the battery and the UC is maintained lower than the DC link voltage. The voltage of the UC can vary in a wide range so the capacitor is fully used. The disadvantage of this method is that two full size converters are necessary which increases the cost.

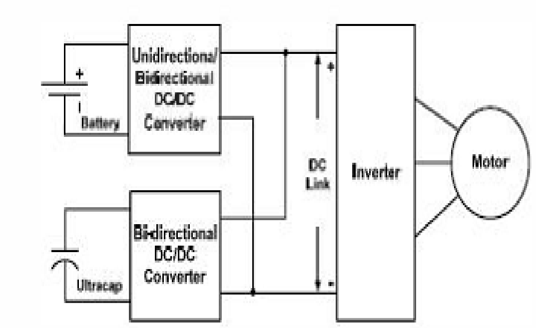

Figure 5. Multiple converter configuration.

F.MultipleInput Converter Configuration

Multiple input converter topologies are proposed in order to reduce the cost of the overall system. The system diagram of the multiple input converters method is shown in figure 6.

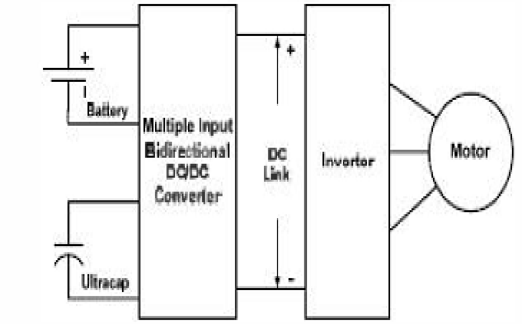

Figure 6. Multiple input converter configuration.

HYBRID ENERGY STORAGE SYSTEM DESIGN

This section deals with considerations which are development of battery/UC discussed in detail. the basic design considered in the HESS topologies is discussed in detail.

A. Voltage Strategy of Battery and Ultra capacitor

In designing a battery/UC HESS, the selection of the voltage strategy depends on the characteristics of the battery and UCs used [4]. Higher voltage capacity for the energy storage device presents a higher demand for the cell balancing circuit. As the number of cells in series increases the cell imbalances grow exponentially [6]. One approach to reduce balancing needs is to use cells with lower performance variations (capacity, internal resistance, and self discharge rate). The matched performance is obtained by cycling a big batch of cells and finding similar cells that can be grouped together. For a better matched performance it requires the need for a bigger batch of cells to select from resulting in increase of the total cost of battery pack. Therefore, depending on the characteristics of the battery and UC cells, voltage tradeoffs between the storage elements need to be made. It is also clear that that in most cases, UCs are easier to balance with lower additional cost. Topology of a HESS depends mostly on the voltage strategy selected [4], [8]. In the following discussion, Vuc, VBall, and VDC are referred to the voltage of the UC bank, voltage of the battery pack, and voltage of DC link, respectively. If $(V_{uc} < V_{Ball} = VDC)$, it indicates that a battery pack is connected directly to the DC link and a UC connected to the DC link through a bidirectional DC/DC converter.The power rating of the DCIDC converter is needed to match that of UC in order to fully utilize its higher power capability. This voltage strategy has an advantage to use the entire range of the UC where a lower voltage UC bank is needed. If $(V_{Ball} < V_{uc} = V_{DC})$, it refers to a switch in positions between the battery and the UC with reference to the previous method. The UC bank is connected to the DC link directly, while the battery is connected through a DCIDC converter. With this the voltage of the battery can be maintained at a lower magnitude so that less balancing issues need to be addressed. If $VBatt = Vuc = VDC$, this means the battery and the UC are directly paralleled and connected to the

DC link. This does not require any DCIDC converter but the working range of the UC is very small. If VBall i- Vuc i- VDC (not necessarily unequal), then both the battery and UC are connected to the DC link through power electronic converters or other mechanisms.

B. Effective Energy Utilization of Ultra-Capacitor

In order to deliver 75% of the energy stored, the voltage of the UC needs to discharge to half of the initial voltage. The major problem related to HESS configuration is the ability to use the UC energy storage effectively. If the UC is connected to the DC bus via a DC/DC converter ($V_{uc} < V_{Ball} = V_{DC}$), 100% of the energy can be delivered theoretically. However, in order to prevent a reverse charge of unbalanced cells a safety margin is allowed. 90% of the UC energy can be delivered when a voltage variation of 66% is permitted. By passively paralleling the battery and UC the voltage of the UC cannot change a lot. Even in an aggressive discharge (within the battery power limits), the voltage of the battery pack can drop only up to 20% of the nominal voltage. The actual energy available is less than 36% because a margin needs to be allowed for the UC to cover higher voltage of the battery pack during charging or regenerative braking.

C. Protection of the Battery

The HESS design is used to fully utilize the significantly higher power limits of the ultracapacitor to support acceleration and fully recover energy through regenerative braking. There are frequent charging and discharging cycles in energy storage systems in automotive propulsion applications which are typically current surges caused by unpredictable regenerative braking. If this surge is injected directly into a battery without regulating, the battery could die very quickly. This is especially true for lithium-ion batteries. The common engineering solution for in a battery ESS to this problem is to provide charging and discharging power limits to the controller. This allows the hybrid system optimizer to follow power limits in order to protect the battery. The discharging power limit ensures that no additional power is drawn from the battery during aggressive acceleration while the charging power limits force the hybrid controller to activate mechanical brake early in order to absorb the portion of extra energy that cannot be taken by the battery. In a Battery/UC HESS system design, it is important to utilize the much higher power limit of the UC to not only protect the battery but also increase the overall performance of the electric drive system. UC technology increases the energy density.

THE PROPOSED HESS

In order to satisfy the real time peak power demands of the power train controller conventional HESS connects the UC via a DCIDC converter. It requires DC/DC converter to have the same power capability as the UC bank or at least higher than the maximum possible demand value. The proposed HESS achieves this by the application of the averaging concept which is illustrated in Figure 7. In the proposed configuration the high voltage DC link is allowed to vary in a predefined ratio. The motor drive is designed to handle the current at the lower voltage. In order to provide peak power demands a higher voltage UC bank is always directly connected to the DC link where as a lower voltage battery is connected to the DC link via a power diode (or a controlled switch). A reduced size bi-directional DC/DC converter is connected between the battery and the UC to convey energy to charge the Uc. The DC/DC converter is always controlled to try to maintain the voltage of the UC higher than that of the battery. Therefore in most cases, the diode is reverse biased.

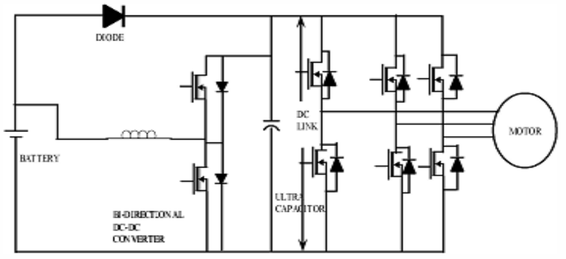

Figure7. Proposed HESS configuration

SIMULATION RESULTS

The computer simulation of proposed converter is done using Mat lab/Simulink and the results are presented. The simulation results indicate that the designed HESS is working as expected.

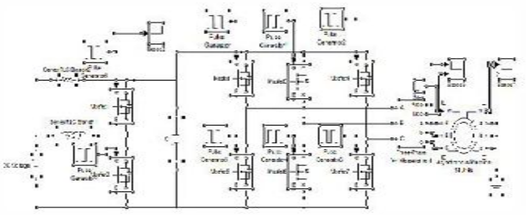

Figure 8: Simulation diagram

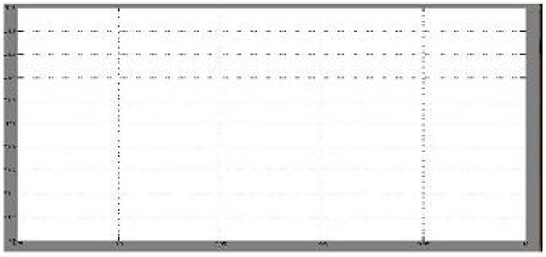

Fig 9: Measured input voltage

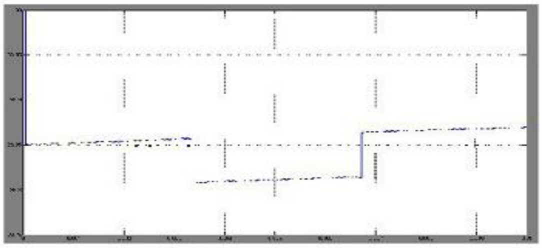

Fig 10: UC voltage Vs Time

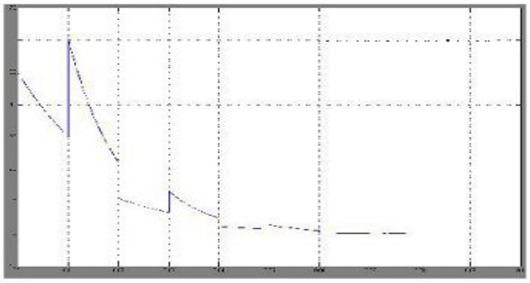

Fig 11: DC/DC converter current Vs Time

CONCLUSION

In this paper, a new HESS design has been proposed. Compared to the conventional HESS, the new design is able to fully utilize the power capability of the ultra-capacitors without requiring a matching power DC/DC converter. The comparative analysis shows that the proposed HESS requires a smaller size DCIDC converter to convey energy to charge the UC bank. A case study and simulations were carried out.

REFERENCES

[I] A. Emadi, S. S. Williamson, and A. Khaligh, "Power electronics intensive solutions for Advanced electric, hybrid electric, and fuel cell vehicular power systems," IEEE Trans\. on Power Electronics, vol. 21, no. 3, pp. 567-577, May 2006.

[2] A. Emadi, K. Rajashekara, S. S. Williamson, and S. M. Lukic, "Topological overview of hybrid electric and fuel cell vehicular power system architectures and configurations," IEEE Trans\. on Vehicular Technology, vol. 54, no. 3, pp. 763 -770, May 2005.