Hybrid Energy Storage System for Electric Vehicle

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***Abstract*— Battery and Ultracapacitor are best hybrid source to provide energy to the electric vehicle. With bi directional converter topology, a link is provided between Ultracapacitor and battery source. This converter is used to frequent charge and discharge of Ultracapacitor from battery. As speed of electric vehicle vary, it required proportional energy to drive the vehicle. With power diode and other circuit components, a simulation circuit is modeled for charging and discharging process of Ultracapacitor and battery hybrid system. Different modes of operation and energy conversion explained.**

***Keywords*—Hybrid Energy Storage System (Ultracapacitor& Battery, Bi directional Converter**

I. Single Energy Source

Energy Storage System (ESS) can supply uninterruptable power supply up to few Wh. No single type of ESS element can simultaneously fulfill all the desired characteristics of an ideal ESS system. Among all ESS, Battery is the most widely used device. It has different performance characteristics such as: cycle efficiency, cost per unit capacity, energy density, power density, cycle life, environmental effect including end-of-life, disposal cost etc. In battery based energy storage system, power density of the battery needs to be high enough to meet the peak power demand and so battery with the higher power density has higher price. To provide a higher demand, battery size should be increased and so its cost also increases. With battery system there are problems related with the battery's condition like, temperature, cycling life, battery's frequent charge and discharge with the variation in the required demand. Batteries life depends on these factors, and it may result in the total battery pack life. Thus, it is required to find another alternative which stores the energy in any other form. In ESS, Ultracapacitor is connected as another device to store the Energy. UC has high power density whereas battery has high energy density. Battery and UC combination will give a better performance for EV. In this paper, an HESS system is presented with different configurations such that Battery and UC will meet certain requirement of voltage and current capacity. Charging and discharging capacity will depend on the SOC. HESS system is used to improve the efficiency of storage system used in past.

II. Battery & Ultra capacitor

In this paper, Batteries and UC are used as HESS. For higher load demand in EV, size of the battery increases with number of cells and size increase in battery will create a voltage balancing problem due to variations in cell capacity, its self discharge rate, temperature capacity, and internal resistance. So it is graceful to use the another ESS device which stores the energy. The UC is better option to be used. Battery and UC are differentiate on the bases of their power density, energy density, cycle life, cycle efficiency, capital cost, self discharge per day. Battery has higher energy density and lower power density, and UC has high power density and lower energy density. Self discharge per day for UC is upto 20-40%, whereas for lead acid and Li-ion are 0.1-0.3%. Capital cost for UC, Lead acid and Li ion batteries are around Rs 3300 per unit, Rs 6200-12,400 and Rs 37,200- 1,55,000 respectively. Operation life of Lead acid and Li ion are 800 and 1200 respectively, whereas for UC, operation life is over 1million .UC provide a better performance in low temperature. With optimal combination of battery and UC can be achieved overall higher efficiency can be achieved.

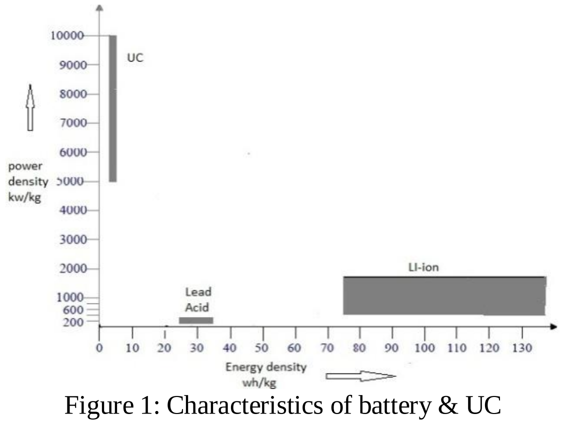

Figure 1: Characteristics of battery & UC

III. Hybrid Energy Storage System

For Battery and UC set, different connections can be made. In which basic parallel connection, Battery and UC are directly connected in parallel without any convertor topology. But with this type of connection the store energy of uccan not be utilized.

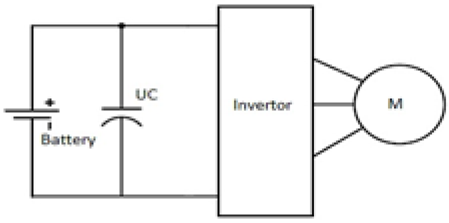

Figure 2: Basic parallel connection

Other one is the Battery and UC are connected with the Bi directional convertor. With connection of Battery and UC as shown in fig, can utilize the UC energy in the wide range and also battery voltage can be maintain at various range with respect to UC. To achieve better working range, cascaded connection of Bi directional converter should use.

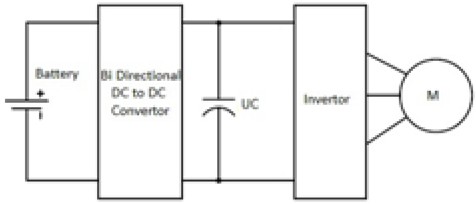

Figure 3: Battery and UC connection

Figure 4, is the connection for storage system. It is simulated and studied in this paper. HESS via bi directional converter and the diode for unidirectional is connected.

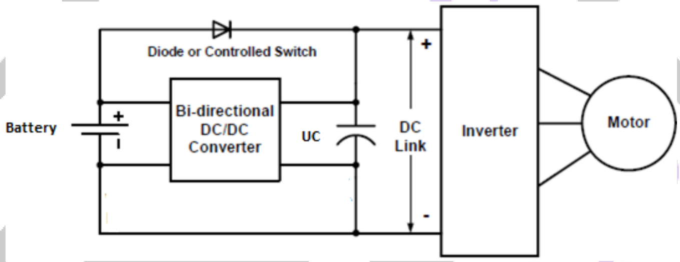

Figure 4: HESS connection

With this type of connection Battery will charge UC and also supply to the Motor. Depending upon the power demand of load side the different operation mode is done.

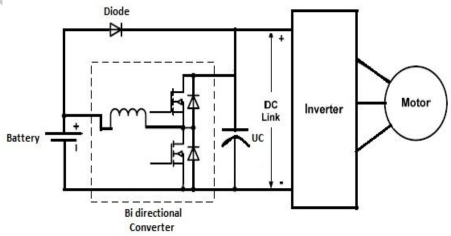

Figure 5: Basic circuit for HESS

IV. Mode of Operation

The total operation of electric vehicle is differentiating in three modes.

Low speed operation mode: If the power demand *Pd*is less or equal to the power of the bi directional converter *Pc* then it is the low speed operation. So, at low constant speed operation voltage across UC *Vuc* is higher then the voltage across the battery *Vb*, so power diode is turn off and battery will supply power to motor through inverter without any discharge or charge process of UC.

High speed operation mode: In case, if the *Pd*is higher then the *Pc*, it is high speed operation. So, at high constant speed operation *Vuc* will be less then the *Vb*, so power diode turn on and it supply power demand directly to the motor through power diode.

Acceleration and Deceleration mode: In acceleration mode, for starting period UC and battery both supply power demand to the motor, but after sometime UC will discharge upto voltage level of the *Vb*. So, after it battery will provide the energy to charge the UC and as well as vehicle drive. In deceleration or breaking mode operation, both battery and feedback energy from the inverter should use to charge the UC. UC will charge from the battery up to its voltage value set, after it only feedback energy will charge the UC.

V. Charging & Discharging

By using this basic circuit for HESS, simulation set up, and battery discharge waveforms are obtained and studied using MATLAB.

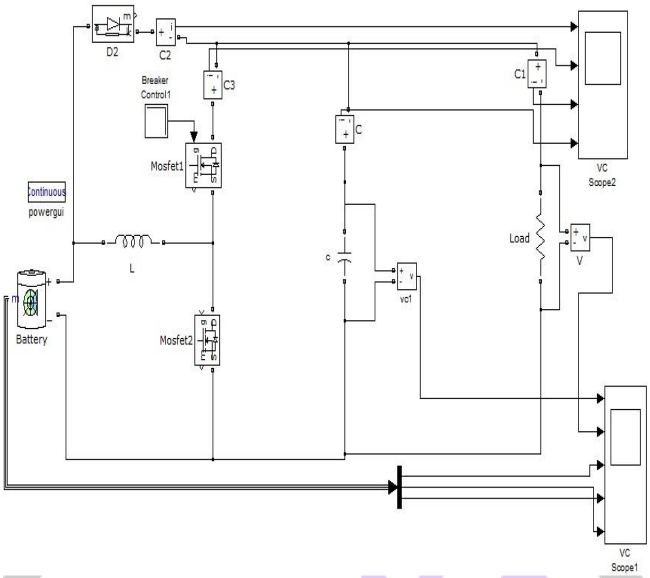

Figure 6: Simulation setup for battery discharge period

TABLE 1. SPECIFICATION OF COMPONENTS

Sr. No.	***Components***	***Specification***
1	Battery	172.8 v 180 Ah Li-ion
2	UC	16.67F
3	Converter	Bi-directional DC-DC converter

THE UC AND BATTERY SPECIFICATION USED FOR SIMULATION ARE SHOWN IN TABLE 1.

Figure 7, Which shows the waveforms for current flow from power diode, MOSFET, load and UC respectively. Figure 8 represent, first two axis for the voltage across the UC and load respectively. Third axis for State of charge of battery and initial SOC set at 60%. Fourth and five axis for voltage and current of battery and SOC can be calculated as,

$$SOC = 100\left(1 - \frac{1}{Q}\int_0^t i(t)\,dt\right)$$

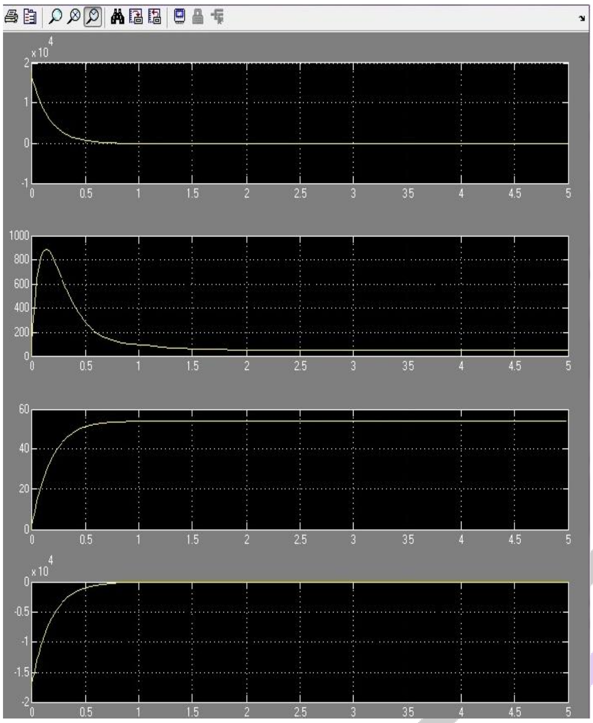

Figure 7: Current waveforms

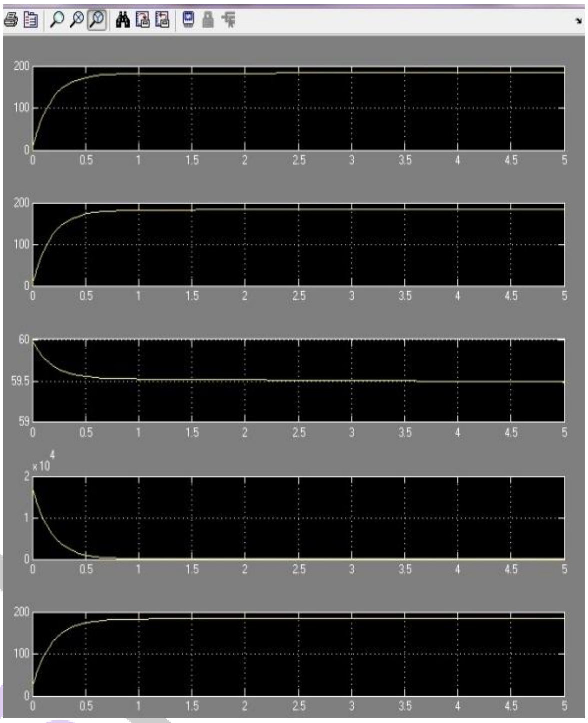

Figure 8: Voltage and battery waveforms

VI. Advantages of HESS

UC can be charged and discharged quickly without any heat generation. Remaining energy level can be measured by measuring voltage across UC. Repetitive charging and discharging can be done. It has wide operating temperature range. UC is green, a maintenance free energy and power delivery solution.

VII. Conclusion

It is concluded that the overall performance of EV can be improved by efficient utilization of power and energy for both sources. With bidirectional converter topology energy can be feedback to charge the UC and so efficiency improved. Size of battery bank is reduced as most of them replaced by UC.

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