# Usage of Ultra Capacitor in Hybrid Energy Storage System for Electric Vehicle

**Harisha S[1] Prof. Nagesh B K[2]**
[1]M.Tech. Student [2]Associate Professor
[1,2]Reva Institute of Technology Bangalore, Karnataka, India

*Abstract*— This paper deals with the simulation study of an ultra-capacitor based energy storage system for electric vehicle. The simulation study in which ultra-capacitor undergoes charging/discharging during buck and boost operation . In this analysis battery is directly connected to bidirectional dc-dc converter followed by ultra-capacitor. Various plots obtained for buck-boost operation. The study focused on speed of the operation during either boost or regenerative mode, ultra-capacitor controls the charge and absorbing the regenerative power from motor and responsible for charging the battery.

***Key words:*** Battery, Ultra-Capacitor (UC), Hybrid Energy Storage System (HESS), DC-DC Converter, Motor, Electric Vehicle

## I. INTRODUCTION

The battery dependent ESS has many disadvantage like i) Low power density ii) Thermal iii) Cell balancing iv) continuously charging and discharging cause worse v) Size and cost. Battery in an electric vehicle suddenly discharge and charges during acceleration and braking action so the life span of battery decreases. Many research shows batteries perform well during constant load. In urban driving condition batteries cannot offer an ideal condition. In the practical condition constant load cannot be maintain for batteries. So in order to reduce the problems of the battery dependent energy storage system. an Hybrid energy storage system (HESS), along with the battery an ultra-capacitor is configured. so the ultra-capacitor have capacity to store more energy during charging and discharging cycles. ultra-capacitor are more efficient and have a longer lifetime since number of discharging cycles is more than batteries .also it as high power density giving higher performance. There are some configuration in which battery and ultra-capacitor is interfaced i) ultra-capacitor/battery combination in which battery is output of the dc-dc converter and ultra-capacitor is the input ii) Battery/ultra-capacitor combination in which ultra-capacitor is output and battery is input of the dc-dc converter iii) In Multiple Input converter combination providing two inputs to the dc-dc converter iv) In Cascaded combination providing two dc-dc converter in cascaded manner in which first converter is connected at the input of second and v) Multiple Converter combination output of two converter connected in parallel rather than cascading.

Most commonly used HESS where the dc link connected across battery, between the UC bank and dc link half bridge converter is placed. Half-bridge converter is a cost problem. Hence a Battery/Ultra-capacitor configuration is used. In this configuration battery is directly connected to converter followed by ultra-capacitor. Ultra-capacitor has capacity to sudden charge and discharge during forward and braking operation.

### *A. Objectives of the Paper*

In Battery/Ultra-capacitor configuration battery is straightforwardly associated with the Bidirectional converter took after by a Ultra-capacitor associated over the load. capacitor under goes charging and discharging cycle. The theme of our paper is to use the ultra-capacitor since it is more efficient for charging and discharging and avoid frequent charging and discharge of battery.

## II. ULTRA-CAPACITOR CONFIGURATION

### *A. Operation of Battery/Ultra-Capacitor HESS Configuration*

The below diagram shown in Fig.1 is a Battery/Ultra-capacitor Hybrid energy storage system design. In this configuration battery directly connected to Bidirectional dc-dc converter followed by ultra-capacitor connected across the load.

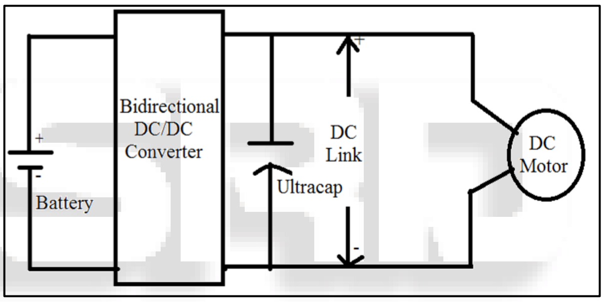


Fig. 1: Battery/Ultra-capacitor configuration

In boost operation the bidirectional converter responsible for forward mode and in buck operation, the regenerative mode. If any load power changes ultra-capacitor is the responsible. Ultra-capacitor discharge when load power required and it as capacity to absorb power from the motor during regenerative mode. So avoid the battery from frequent charging and discharging cycle.

### *B. Generation of PWM Signal for Lower and Upper Switch:*

The bidirectional dc-dc converter switches operated based on operation mode; boost or buck mode

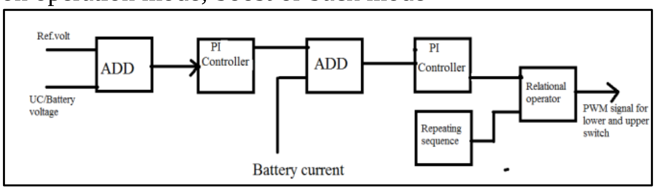


Fig. 2: Block diagram of PWM Sub-system

In the above block diagram shown Reference Voltage and actual voltage obtained is compared an error signal obtained. This error signal is subjected to PI controller. Controller after tuning an control signal is obtained. This control signal again compared with input battery current output is error signal. This error signal again passed to PI controller control signal is obtained. The control signal is compared with ramp signal an PWM signal is the output. For the proper switches, signals are applied based on the mode of operation

## III. SIMULATION RESULTS

### *A. Boost Operation*

As shown in Fig.3 during boost operation the switch S2 is ON whereas switch S1 is off and diode of switch S1 is forward biased. when switch S2 is ON the current in the inductor raises. the energy stored in the inductor must flow somehow, hence when switch S2 is OFF the current in the inductor flows to the Ultra-capacitor through diode of switch S1.the energy of the inductor is transferred to Ultra-capacitor. MATLAB is used to simulate the performance.

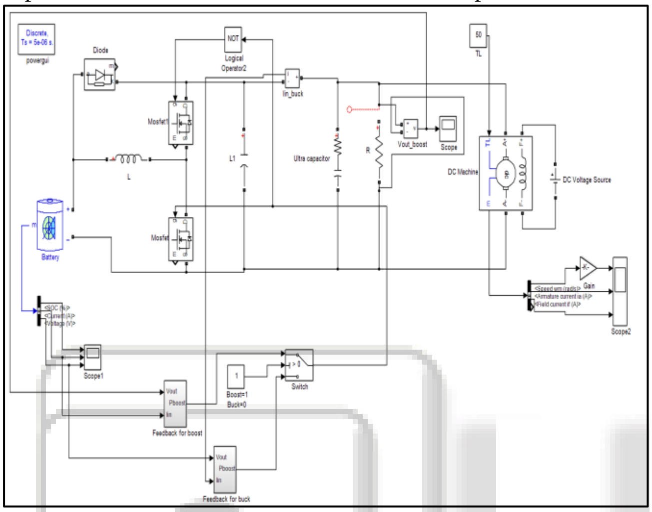

Fig. 3: Closed loop simulation circuit for a Battery/Ultra-capacitor HESS

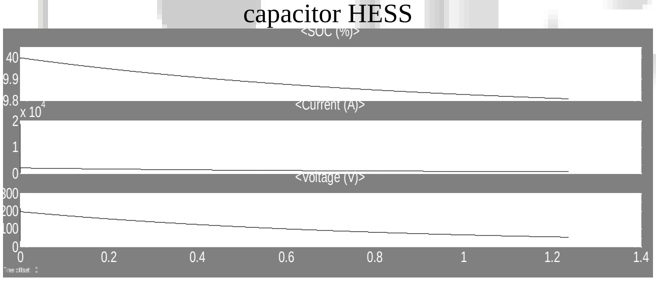


Fig. 4: Simulation result for battery output SOC, Current, Voltage

When positive torque given to load, the sudden change in the load power is supported by Ultra-capacitor. as shown in the Fig. 4 state of charge(SOC) decreases from 40% ,Input voltage decreases from 200,current also decreases. The Speed, Armature current, and Field current of the DC motor during ultra-capacitor charging is shown in Fig. 5

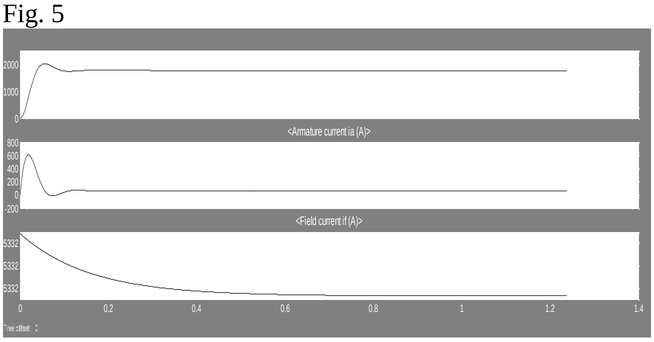


Fig. 5: Speed, Armature current, and Field current of dc motor during boost mode

### *B. Regenerative Mode*

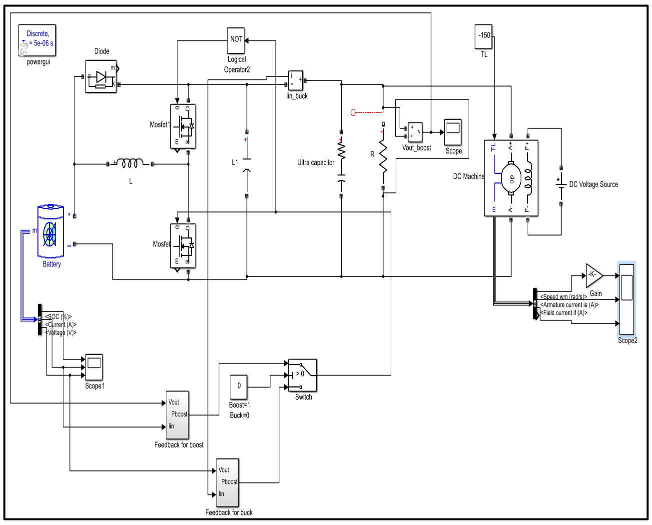

Fig. 6: Closed loop simulation circuit

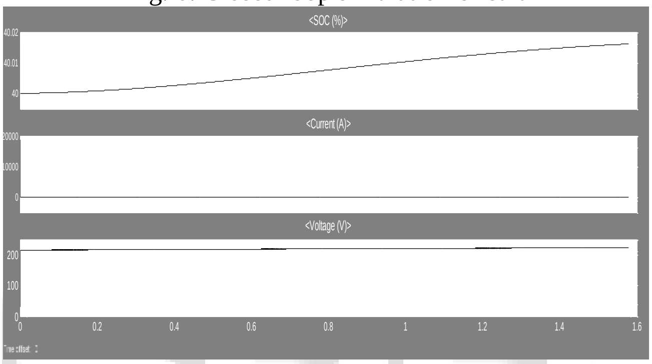


Fig. 7: Simulation result for Battery output State of charge (SOC), current, voltage

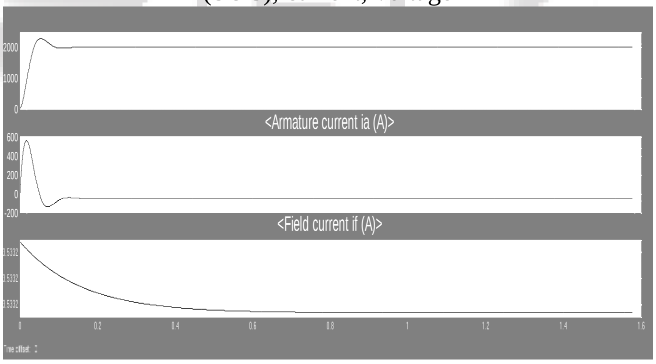


Fig. 8: Seed, Armature current, and Field current of dc motor during Regenerative mode

As shown in Fig. 6 during regenerative mode switch S1 is ON whereas switch S2is OFF. and diode of switch S2 is forward biased. when switch S1 is ON the current in the inductor raises. the energy stored in the inductor must flow somehow, hence when switch S1 is OFF the current in the inductor flows to the Battery through diode of switch S2.the energy of the inductor is transferred to Battery.

When negative torque is applied regenerative braking occurs, the energy released during braking is absorbed by ultra-capacitor. this absorbed energy is sent back to the battery through buck mode. . as shown in the Fig. 7 state of charge(SOC) increases from 40% ,Input voltage increases from 200,current also increases. The Speed, Armature current, and Field current of the DC motor reduces during regenerative mode is shown in Fig. 8

| Components | Value |
|---|---|
| Battery | 200V |
| Inductor | 54.6e-6 |
| MOSFET | STP20NM60 |
| Inductor L1 | 1.9e-3 |
| Resistor | 0.001 |
| Ultra-capacitor | 16.6 |
| Diode | MUR460 |
| Motor | DC motor |

Table 1: Specification of the Proposed Closed Loop Topology

## IV. Conclusion

In this paper simulation analysis is done in which ultra-capacitor/battery combination is used in hybrid energy storage system. In this combination control mechanism speed of the operation during either boost or regenerative mode, the ultra-capacitor absorbs charge during regenerative mode and send back to battery. Ultra-capacitor are more efficient and have a longer lifetime since number of discharging cycles is more than batteries. hence avoid battery from frequent charging and discharging cycle.

## References

[1] "Performance Evaluation of Ultra-capacitor in Hybrid energy storage system for Electric Vehicles"

[2] Jian Cao, and Ali Emadi “A New Battery/Ultra-Capacitor Hybrid Energy Storage System for Electric, Hybrid, and Plug-In Hybrid Electric Vehicles”, IEEE Transaction on Power Electronics,Vol.27, No.1, January 2012.

[3] S. M. Lukic, J. Cao, R. C. Bansal, F. Rodriguez, and A. Emadi, “Energy storage systems for automotive applications,” IEEE Trans. Ind. Electron.,vol. 55, no. 6, pp. 2258–2267,Jun. 2008

[4] S.M. Lukic, S. G.Wirasingha, F. Rodriguez, J. Cao, and A.Emadi, “Power management of an ultra-capacitor/battery hybrid energy storage system in an HEV”,Proc.IEEE Veh. Power Propulsion Conf., Windsor,U.K.,Sep.2006, pp. 1–6

[5] A.C. Baisden and A. Emadi, “An ADVISOR based model of a battery and an ultra-capacitor energy source for hybrid electric vehicles,” IEEE Trans. Veh. Technol., vol. 53,no.1,pp.199–205,Jan.2004.