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Active Balancing Scheme for Battery Management System

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Abstract **The BMS system of the battery is related to a number of control parameters like temperature sensors, cell balancing, improving battery efficiency, improving battery life, etc. The working area of this particular project is related to the cell balancing of the EV battery. For those batteries, a battery management system is needed to improve battery life and increase its efficiency. A Quasi Resonant Zero Current Switching (QRZCS) technique is designed to get less losses and higher energy transfer efficiency. The simulation and experimental results shows that the proposed QRZCS battery equalization schemes can achieve bidirectional battery equalization performance and reduce the MOSFET transistor switch power losses by more than 95% and increase the efficiency. The results further compared with conventional battery equalizer during an identical equalization process.**

Keywords —Active balancing system; Quasi resonant converter; Buck- Boost converter; Fly back converter.

I. INTRODUCTION

Now a days electric vehicles are running worldwide. While fulfilling that need the world is facing to the problems regarding energy management. There are many players throughout the world who are searching best solution to solve this energy management problem. Because it is directly affecting to the sources who are producing electric energy. In electric vehicle, there is a battery system to run the vehicle. But in battery system energy need to be maintained to control the range of the vehicle, to enhance the performance of vehicle and to improve the life of battery. To achieve this, Battery Management System (BMS) is different working sector where all the care of battery and battery related issues is taken to solve under growing electric vehicle problem caused be battery. There are various theories present on active balancing schemes. The area where we are interested belongs to the converters such as DC to DC converter, Fly back converter, Buck converter, Boost converter, Buck-Boost converter, Cuck converter, and Luo converter

The present thesis is based on one issue comes in BMS that is ‘Cell balancing’. Cell balancing has become a basic need of battery and also becoming a reason for battery life. In the section of cell balancing, the charge between the cells of batteries is balanced or controlled in such a manner like every cell will experience the same charge. The boost dc to dc converter is used for equalizing the voltage gap for large balancing current [1]. ZCS (Zero Current Switching) belongs to the quasi-resonant converter circuit to reduce the switching losses. It includes a buck-boost converter, which improves efficiency by 20% to 30 % as compared to other conventional types. The disadvantage associated with this particular scheme is the lower equalizing current increases the equalization time during the charge balancing process [3].

There are two types of cell balancing:

1) Active cell balancing.

2) Passive cell balancing.

Current thesis is based on active cell balancing which is more efficient than passive cell balancing. It proposes a cell voltage equalizing control method by using a bidirectional dc-dc converter with QR ZCS .The cell voltages are controlled by the driving PWM signals corresponding to the respective cell voltage through the equalization algorithm. The proposed battery equalization scheme can achieve zero current soft switching, and furthermore it can reduce the MOSFET switching loss for increasing the energy transfer efficiency of battery. A design example for the series connected lithium ion battery strings was given to demonstrate.

II. . PROPOSED EQUALIZATION METHOD

A. Structure of proposed method:

Fig.1. shows a battery cell equalization system with series-connected battery cells having individual cell equalization circuits. Cells are named Vb1, Vb2, Vb4, etc. The series-connected cells can be extended up to ‘n’ cells.

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The cell balancing unit is connected between two adjacent cells. The bidirectional battery equalizer is composed of MOSFET switches body diodes and one resonant circuit having one capacitor and two inductors. To analyze the battery state, the battery state control is connected to each cell. The whole battery equalization control is connected to each cell balancing unit. A zero soft switching technology based on the quasi-resonant converter technique can be used to reduce the battery equalizer switching losses and increasing equalization efficiency with a low EMI battery equalization system. To achieve Quasi-Resonant Zero Current Switching (QRZCS), the resonant tank circuit of Lr, Lr+1and Cr elements must be constructed. A large energy storage Lr and two power MOSFETs with two diodes are working as balancing control switches.

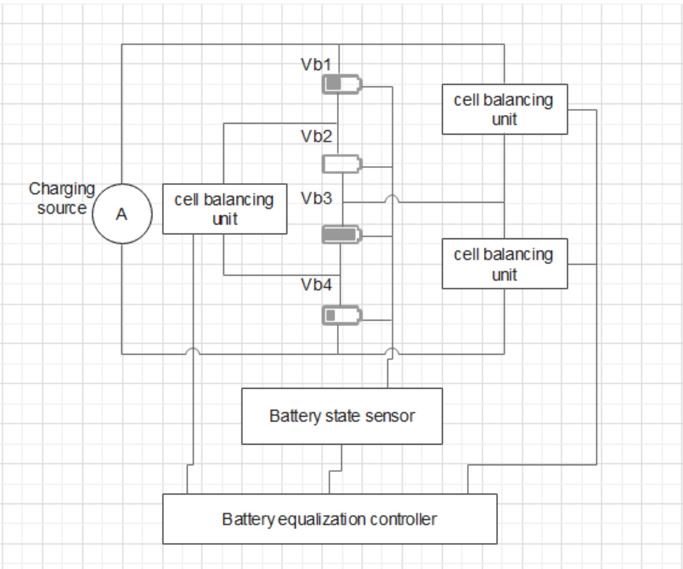

Fig. 1. System configuration of proposed cell equalization scheme.

The energy transfer direction between two adjacent cells is determined by a voltage difference between them or battery residual capacity (BRC). If Vbi > Vbi+1 and/or BRCi>BRCi+1, Qi is turned on, and inductor L stores energy from Vbi during the period DTs. During the other (1-D) Ts periods, Qi is turned off, and the body diode is forced to turn on. The stored energy in L is then discharged to Vbi+1 to act as a controlled charging current source for cell balance according to the energy transfer direction. If Vbi<Vbi+1 and/or BRCi<BRCi+1, Qi+1 is turned on during the period DTs and turned off during the other (1-D) Ts period and the body diode Di is forced to turn on, the stored energy in Lis discharged into cell Vbi, and the equalization energy is transferred to the reverse direction to balance the battery string adjoining cell voltage. The Lr and Cr are constructed as the resonant tank to achieve the QRZCS function for the symmetrical and bidirectional battery equalizer.

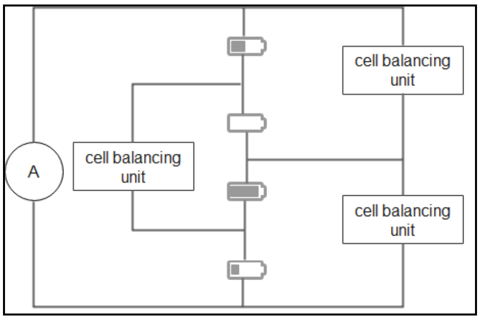

Fig.2.Proposed cell balancing system at cell unbalance. Fig (a) System when cells are unbalanced.

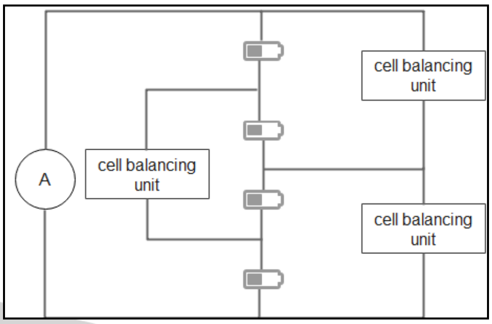

Fig (b) System when cells are balanced.

B. Operation of proposed cell balancing method:

Fig.2 (a). Shows the schematic of cells applied to the cell balancing system before balancing and Fig.2. (b).shows the schematic of cells applied to the balancing system after taking the cell balancing action. Here from these two diagrams how the cells become balance from unbalance condition can be seen. In Fig.3. One Mat Lab function block is placed which controls the feedback signals going to the MOSFETs via the signal generator. For that purpose, the Mat Lab function block takes the output from two capacitors as a cell voltage and differentiates between them by using the function below and set up a signal to MOSFETs operation to perform cell balancing action.

Where u and v are the inputs to the Mat Lab function block from two capacitors in the form of voltage. According to a condition they will compare with each other,

```
function y = fcn(u,v)
if(u<=v && v>=u)
 y=1;
 else
 y=0;
 while true
 end
```

This is the code for performing balancing action with the unbalanced cells. If there is any unbalanced of cells is seen by comparing the voltage levels, it will generate output as '1'. If the two voltages are the same then it will generate

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output as '0'. For the cells more than two, each cell will be connected to the sensor unit. Sensor unit will sense the current-voltage level of the cell and send it to the battery equalization unit and through the MatLab function block cell balancing will be performed.

III. Simulation and Experimental Results

Fig.3. shows simulation models for quasi-resonant-based active balancing technique and buck-boost converter-based active balancing technique. As QRZCS method is the proposed method for further discussion. For simplicity reasons, the battery storage elements were assumed to be capacitors established in the MATLAB simulation model. In practical simulations, the capacitance value was chosen smaller than the theoretical value to stabilize and speed up the simulation process. The battery initial voltages in the simulations were set as 6.0V and 7.0V. The circuit parameters of the modified QRZCS battery equalizer were Lr=270 mH, Lr+1= 59.6 mH, and Cr=1.66 μF. The capacitance of the represented battery was selected as 5 mF with ESR= 0.01Ω. The switching frequency for this converter was chosen as 16.67kHz and the duty ratio is determined as D=0.5(6).

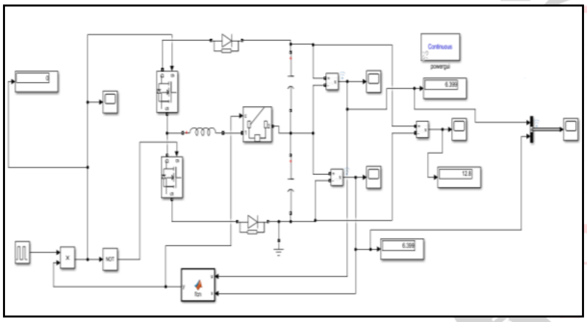

Fig.3.Simulation model for active cell balancing method. Fig(a)Simulation model for buck-boost converter-based cell balancing method.

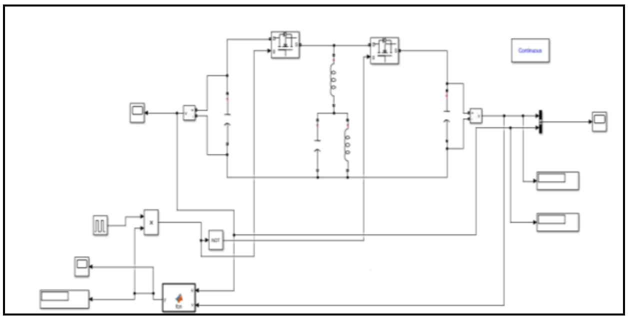

Fig (b) Simulation model for proposed QRZCS cell balancing method.

The proposed battery equalization system was designed to operate at the zero-current-switching mode that can obtain a lower switching loss to improve the cell voltage balancing scheme efficiency.

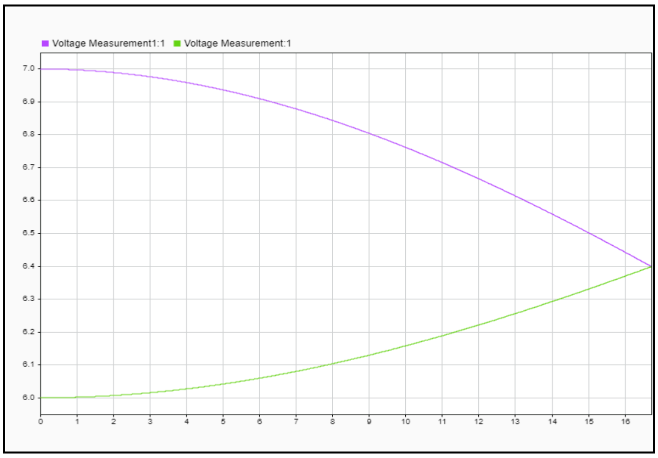

Fig.4. Simulation results for proposed active balancing system. Fig (a) Simulation results for buck-boost converter-based cell balancing scheme.

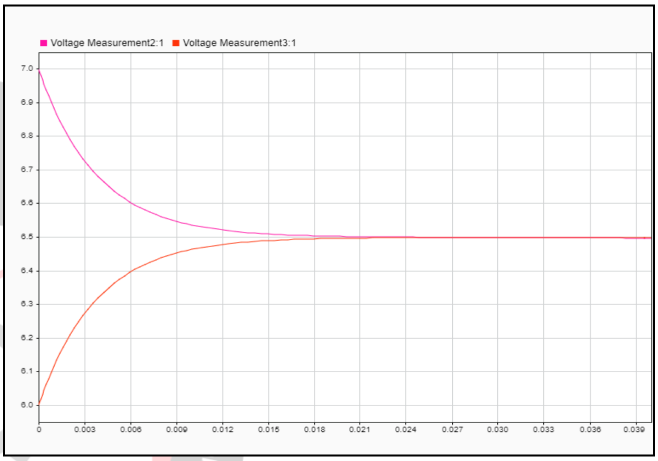

Fig (b) Simulation results for QRZCS based cell balancing scheme.

Fig.4. show the experimental results of a battery pack, cell voltage trajectories for VB1<VB2, respectively. The experimental results are meeting the theoretical expectations and simulations [6]. It demonstrated that the proposed cell balancing system is designed to perform the cell voltage balancing controlled under zero current switching of the bidirectional battery equalizer. After balancing all the cell voltages within the resolution limit of the analog-to-digital converter, the BMS will send an executed command to cut off the MOSFETs and to stop the cell voltage balancing process of the battery equalizers.

IV. Comparison of Proposed Balancing Scheme with Different Methods

Table no.1. Shows the comparison chart of buck-boost converter-based active balancing method and QRZCS based active balancing method. Fig.4. (a) and (b) show that the results getting from the QRZCS method are more efficient and quick as compared to the buck-boost converter method.

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	Buck-boost converter	QRZCS converter
Components	2 MOSFETs, 1 Inductor,2 diodes	2 MOSFETs,1 capacitor,2 Inductors
Designed parameters	L=58H	L1=59.9µH L2=270µH Cr=4µF
Switching parameters	D=0.5, fs=16.67kHz	D=0.5, fs=16.67kHz
Simulation time	More as compared to the proposed method	Less as compared to the buck-boost converter
Average energy transfer efficiency	98.44%	99.969%

Table no 1.Comparison table for buck-boost converter cell balancing method and QRZCS based cell balancing method.

V. Conclusion

The QRZCS active balancing cell equalization system has great advantages over other active balancing methods like the buck-boost converter-based method, fly back converter-based method [1]. The cell balancing control schemes based on the QRZCS converter theory for the bidirectional cell equalization of a series-connected battery string have been studied. It is found that these cell balancing control schemes possess interesting properties such as reducing the switching loss, increasing the battery equalization efficiency, and significantly extending the battery life and battery string capability. Simulations and experimental results have been performed to verify the theoretical analysis. A comparison has also been made between ICE without and with QRZCS operations for lithium-ion battery equalization. It is shown that the modified QRZCS battery equalizer is more suitable for low-cost and high-efficiency battery pack applications.

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