A Review of Active and Passive Cell Balancing in Hybrid Electric Vehicle

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1.Abstract

Cell Balancing process is crucial for keeping battery lifespan and protecting the battery cell in hybrid electric vehicles. Li-ion batteries are the most used cells in hybrid electric vehicles. These batteries are influenced by various features such as over-voltage, undervoltage, overcharge and discharge current, thermal runaway, and cell voltage imbalance etc. Due to cell imbalance the battery capacity may decrease very rapidly. Here comes the importance of battery monitoring and balancing system. Monitoring system is used to monitor the cell voltage levels in a pack of cell.To increase the lifetime of the battery pack, the battery cells should be frequently equalized to keeps up the difference between the cells as small as possible. Passive and Active cell balancing methods are the two important cell balancing methods used to equalize the charge level in a pack of cell. These methods are based on cell voltage and state of charge (SOC). The passive cell balancing technique equalizing the SOC of the cells by the dissipation of energy from higher SOC cells and formulates all the cells with similar SOC equivalent to the lowest level cell SOC. The active cell balancing transferring the energy from higher SOC cell to lower SOC cell, hence the SOC of the cells will be equal.

2. Introduction

Batteryisanessentialenergystoragedevicewhichplaysakeyroleinindustries,telecommunication system, electric vehicle, Hybrid electric vehicle and smart grids. Thereare four main kinds of batteries used in electric cars: lithium-ion, nickel-metal hydride,lead-acid, and ultracapacitors.in recent days Li-ion batteries are integral part of electricvehicle because of its advantages like f high energy density, long cycle life, low self-discharge rate and low weight. Sometimes a single Li-ion battery may not be able toprovide the energy demand of the electric vehicle. To attain that demand its necessary toincrease voltage or current level by connecting the batteries in series and parallel. But in apack of battery each battery may have different internal resistance, aging rate, internalcombination etc.. which may lead to inconsistency in state of charge level (SOC)of packbatteries. In order to provide the safe operation, the functioning of the battery shouldmonitored accurately. In EVs and HEVs a battery management system will monitor thefunctioning of the battery. The BMS protects the cells from harmful operation, in terms ofvoltage, temperature, and current, to achieve reliable and safe operation, and balancesvarying cell states-of-charge (SOCs) within a serial connection. The B-TMS controls thetemperature of the cells according to their specifications in terms of absolute values andtemperature gradients within the pack. One of the important key functions of BMS is thecell balancing method. The effective cell balancing improvement of battery pack energyefficiency, cycle life and safety.

According to energy dissipation method battery cell balancing is divided in to Active andPassive Cell balancing. Passive balancing dissipates excess energy in the form of heatthrough a shunt resistor or switched shunt resistor. This method of cell balancing is lesscostlier, simple, convenient and small size. In active cell balancing energy is transferredfrom high energy cell to low energy cell by employing inductors, capacitors converters etc.Compared to passive cell balancing this method saves energy in the battery module whichincreases system efficiency. This balancing method is fast but it is complex and costlier. Inthis article, a comparative analysis was done for the basic Active and Passive Cell balancing topologies based on cell balancingtime, power losses, cost, electronic control, and application.

3. Methodology

The main function of Battery Management System is the monitoring and balancing battery cell in a pack of battery. The battery cell imbalance is mainly due to intrinsic and extrinsic factors. The factors which are associated with manufacturing process which leads to variation in internal resistance are intrinsic factors and the extrinsic factors are mainly series/parallel connection, heat dissipation etc. At balance condition State of charge of all battery cells will be equal. The importance of cell balancing is to equalize the voltage and SOC among the battery cells when they fully charged. The main cell balancing schemes are active and passive methods.

Passive cell balancing

Passive cell balancing method is relatively simple compared to the active cell balancing method. In this method, the cells with excess energy are discharged in the form of heat through a bypass resistor. The fixed shunting resistor and switched shunting resistor are the basic types of passive cell balancing topologies. Passive balancing consists of a resistor in parallel to each cell, controlled by the cell voltage monitoring chip. The intent is simply to discharge the cells at higher SOCs (or higher remaining charge) to match the rest of the cells. In Fixed shunt resistance technique cell voltage is balanced by connecting the fixed resistor in parallel with each series connected cell based on the required cell balance current. The balancing current is dissipated through the resistor which limits the voltage of each cell. In Switching shunt resistor technique cell voltage is balanced by connecting the resistor in parallel with each series connected cell through controlled on/off semiconductor switches or relays. This method requires a controller for controlling the switching operations.

Fixed shunt resistor method

The fixed shunt resistor cell balancing circuit is as shown in Figure. Where, V1, V2, V3, V4, …Vn is each cell voltage which is connected in series and R1, R2, R3, R4, …Rn are fixed shunt resistors of each battery cell. This technique balances each cell voltage by connecting the fixed resistor in parallel with each series connected cell based on the required cell balance current. The balancing current is dissipated through the resistor which limits the voltage of each cell.

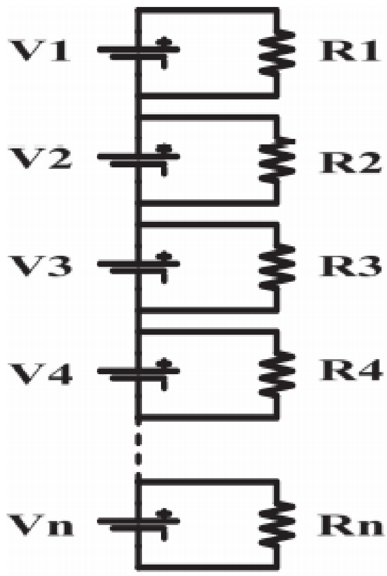

Fig 1. Fixed Shunt Resistor Method

This circuit is very simple, hence it requires less number of components and low cost. But the disadvantage of this technique is to provide the energy losses due to the energy are dissipated as heat in all the cells during balancing operation

Active cell balancing

Active cell balancing System uses storage elements such as capacitors or inductors which transfer the energy from higher charge cell to lower charge cell until all the cells are balanced. Capacitors based, inductors based, and power electronic converters based balancing system are the most common active cell balancing methods. Capacitor based cell balancing method include a charge shuttling between battery cells and capacitor. Charge from the higher energy cell is released, that charge must be stored in capacitor, and then transfer into lower energy cell. This technique is known as energy conversion method in which unequal energy is transferred from a higher energy cell or group of cells to a lower energy cell or another group of cells using magnetic components such as inductor or transformer.

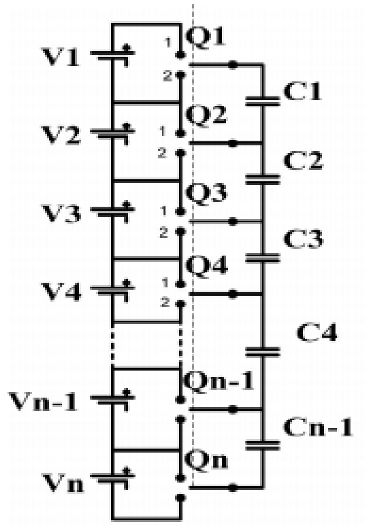

Fig 2. Active Cell Balancing

Comparative Analysis of Various Cell balancing topologies

Scheme	Advantage	Disadvantage
1.FixedResistor	Cheap.Simpletoimplementwithasmallsize.	Notveryeffective. Inefficientforitshighenergylosses.
2.ShuntingResistor	Cheap,simpletoimplementandFastequalizationrate. Charginganddischargingbutnotpreferablefordischarging. SuitableforHEVbutforEVa10mA/Ah resistorspecified.	Notveryeffective;Relativelyhighenergylosses Therequirementforlargepowerdissipatingresistors. Thermalmanagementrequirements.
3.Switched Capacitor	Simplecontrol.Charginganddischargingmodes. Lowvoltagestress,noneedforclosedloop control.	Lowequalizationrate. Highswitchesnumber.
4. Single SwitchedCapacitor	Simplecontrol.Charginganddischargingmodes. Onecapacitorwith minimalswitches.EVand HEVapp.	Satisfactoryequalizationspeed. Intelligentcontrolisnecessarytofasttheequalization.
5.DoubleTiered SwitchedCapacitor	Reducebalancingtimetoquarterthantheswitchedcapacitor. Charginganddischargingmodes.EVandHEVapplications.	Satisfactoryequalizationspeed. Highswitchesnumber.
6.Modularized Switchedcapacitor	Lowvoltageandcurrentstress. Charginganddischargingmodes	Complexcontrolisneeded. Satisfactoryequalizationspeed.
7.single Inductor	Fastequalizationspeed.	Complexcontrolisneeded.Switchescurrentstress. Filteringcapacitorsareneededforhighswitchingfrequency.
8.MultiInductor	Fastequalizationspeed. Goodefficiency	Lesscomplexcontrol.Needsaccuratevoltagesensing. Chargingmodeonly.Switchescurrentstress. Filteringcapacitorsareneededforhighswitchingcurrent.
9.SingleWindings Transformer	Fastequalizationspeed. Lowmagnetic losses.	Highcomplexitycontrol.Expensiveimplementation. Toaddoneormorecells thecoremust bechange.
10.MultiWindings Transformer	Rapidlybalancing.Noclosed-loopcontrolsarerequired. Suitableforboth EVandHEVapplications	Highcost.Complexitycontrol. Thecore willbechangedifcellormoreareadded.
11.Multiple Transformers	Fastequalizationspeed.Canbemodularized EVandHEVapplications. Newcellseasilyadded.	Highcost.Complexitycontrol. Satisfactoryefficiencyduetomagneticlosses.

Table 1: Comparative analysis of cell balancing topologies.

Result

This comprehensive study includes the comparative analysis of Active and Passive Cell balancing topologies in Hybrid Electric Vehicle. The balancing methods are grouped into 3 categories according to their nature of balancing. Operation principles of each method were explained. This battery model features by State of Charge (SoC), State of Health (SoH), cycle number prediction, variable parameters in function of SoC, temperature and cycle number with a parameters variation between cells.

A comparison chart of the balancing methods was shown in Table I. Generally for low power application the switching shunt resistor is good with its low cost, small size and very simple control. For simple, active control selecting the switching capacitor is the right choice and it’s good for HEV application but it takes long equalization time. In case of fast equalization time switched inductor and transformer is suitable but there is a need to a complex control system as well magnetic losses. Energy converter superior for medium and high power application HEVs.

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