CELL BALANCING IN BATTERY MANAGEMENT SYSTEM

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DEDICATION

This project report is dedicated to my adored wife, Jyolsna, who encouraged and inspired me endlessly in my journey to pursue my studies in this field. Without her support and motivation, I would not have completed this work.

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ABSTRACT

The common subsystems of battery management system (BMS) in Electric Vehicle are SOC estimation, cell balancing and thermal management. The subsystems of the BMS are required to operate in real time and rapidly charging and discharging conditions. Besides, the BMS should be properly designed so that it can operate in harsh environment. Cell balancing is a very important subsystem of BMS which will prolong the life of battery. In this aspect, cell balancing system is not only covers the task of protecting the cells, it also includes the task for charge equalization among the cells. The most common type of cell protecting system applied in electronic device is interruption of the charging and discharging of the battery to avoid the battery in reaching its maximum and minimum allowable voltage. On the other hand, the charge imbalance among batteries may cause a slight mismatch on capacity or temperature differences of series connected batteries. The charge imbalance occurs in the form of unequal voltages along the battery string. The two major categories of cell balancing methodologies are active methods and passive methods. In this project, all the categories of cell balancing will be studied extensively, and an efficient and suitable converter based active method is proposed and simulated using MATLAB/SIMULINK.

ABSTRAK

Subsistem umum untuk sistem pengurusan bateri (BMS) dalam Kenderaan Elektrik adalah anggaran SOC, pengimbangan sel dan pengurusan terma. Subsistem BMS ini diperlukan untuk beroperasi dalam masa nyata dan dalam keadaan pengecasan yang laju dan menyahcas. Selain itu, BMS mestilah direka dengan baik supaya dapat beroperasi dalam persekitaran yang lasak. Pengimbangan sel adalah subsistem BMS yang sangat penting dalam melanjutkan jangka hayat bateri. Dalam aspek ini, sistem keseimbangan sel bukan sahaja melindungi sel-sel, ia juga dapat menyama-ratakan cas-cas antara sel. Sistem perlindungan sel yang biasa digunakan dalam peranti elektronik ialah gangguan pada pengecasan dan penyahcasan bateri untuk mengelakkan voltan pada bateri mencapai tahap maksimum dan minimum yang dibenarkan. Sebaliknya, ketidak-seimbangan caj antara bateri boleh menyebabkan sedikit ketidak-serasian kapasiti atau perbezaan suhu untuk bateri yang bersambung secara siri. Ketidak-seimbangan caj berlaku dalam bentuk voltan yang tidak sama disepanjang rantaian bateri tersebut. Dua kategori utama dalam kaedah pengimbangan sel adalah kaedah aktif dan kaedah pasif. Dalam projek ini, semua kategori pengimbangan sel akan dikaji secara meluas, dan kaedah aktif berasaskan penukar yang cekap dan sesuai dicadangkan dan disimulasikan menggunakan MATLAB / SIMULINK.

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LIST OF ABBREVIATIONS

AB	-	Auxiliary Battery
BBC	-	Buck Boost Converter
BC	-	Bidirectional DC-DC Converter
BMS	-	Battery Management System
C	-	Capacitance
DC	-	Direct Current
DTSC	-	Double Tiered Switched Capacitor
EV	-	Electric Vehicle
EHV	-	Electric Hybrid Vehicle
F	-	Frequency
FR	-	Fixed Resistor
I	-	Current
ICE	-	Internal Combustion Engine
IMB	-	Internal Module Balancing
M	-	Module
MSI	-	Multi Switched Inductor
MWT	-	Multi winding Transformer
RUL	-	Remaining Useful Life
SC	-	Switched Capacitor
SR	-	Shunt Resistor
SoC	-	State of Charge
SoH	-	State of Helath
SSC	-	Single Switched Capacitor
SSI	-	Single Switched Inductor
SWT	-	Single Winding Transformer
T	-	Temperature
UC	-	Unidirectional DC-DC Converter
V	-	Voltage

LIST OF SYMBOLS

τ	-	Time Constant
T	-	Period

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CHAPTER 1

INTRODUCTION

1.1 Research Background

In the modern automotive era, a massive shift in the drive train technology is right around the corner. The shift involves a complete change from Internal Combustion Engines (ICE) to an electric drivetrain. This relates to one area in the EV that is limiting the adoption of electric drivetrains and that is the battery. The battery is the main limiting factor on the driving range, charging speed, and power capabilities [1]. The battery also contributes most of the electric vehicle drivetrain weight, cost, and is the factor by which the lifetime of the drivetrain is evaluated. Battery technology in the last 20 years has greatly improved over the batteries used in the first modern era EVs. The building blocks of any EV battery are the battery cells which are single cells. The cells are arranged into series or parallel strings to get the desired nominal voltage and capacity. The assembly of series cells increases the nominal voltage of a module and keep the same capacity, which is rated in Amperehours (Ah). The assembly of parallel cells will keep the same nominal voltage but increase the capacity in Ah. In a module there are usually one or more temperature sensors as well as voltage sense leads for the BMS to connect to. Sometimes the module itself may have a current sensor so the individual current of each module can be monitored but typically the current is measured at the terminals of the whole battery pack. The battery pack is then assembled with many modules, once again, in series or parallel depending on the design specifications. At the battery pack level all the cooling channels, are connected to the modules, these cooling channels can be air or liquid but typically a liquid cooling system is chosen as it allows for more control of the cell temperatures as well as a more compact battery pack design. The battery pack in an EV can be a single large pack in one container or a multitude of battery packs spread around the vehicle.

Battery management system (BMS) is emerged as an unavoidable subsystem of the control and monitoring system of battery applications mainly in electric vehicles (EVs) and hybrid electric vehicles (HEVs). The objective of the BMS are protection of battery cells from damage, prediction of failure and life extension and to maintain the battery system in an accurate and reliable operational condition.

Reliable and accurate operation of battery is achieved by protecting the battery system from damage, predicting the failures and increasing the life of battery by monitoring its health. Imbalance of battery pack cells is a major issue in the battery system life management. The BMS performs several tasks such as measuring the system V, I, T, the cells' SoC, SoH, and RUL estimation, protecting the cells, thermal management, controlling the charge/discharge procedure, data acquisition, communication with on-board/off-board modules, monitoring, storing historical data and most important task is the cell balancing [10].

The BMS can have many configurations according to the tasks that should be performed. An example of a BMS system used in electrical vehicle application is shown in Figure 1.

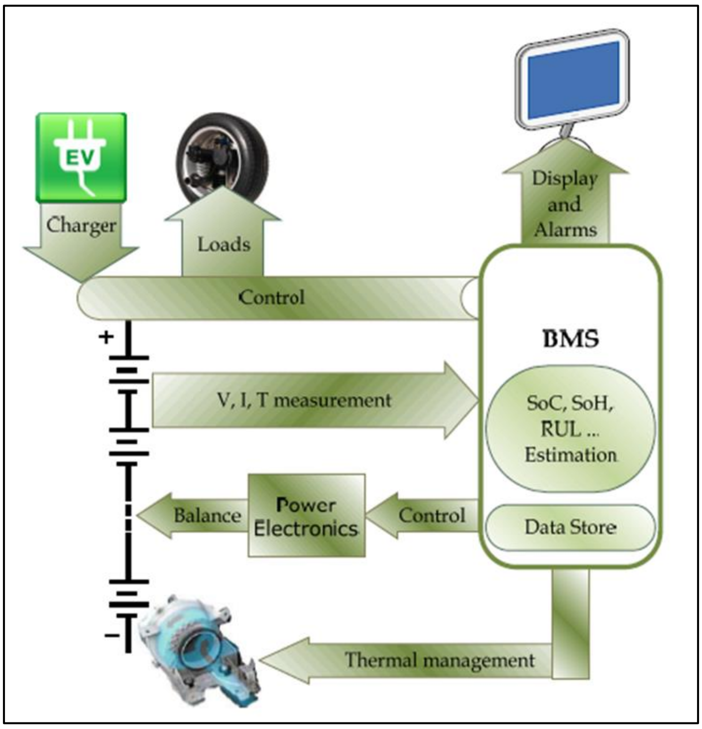

Figure 1.1 BMS Block Diagram [10]

Imbalance of cells in battery packs is an essential factor affecting the battery life. The individual cell voltage will drift apart overtime if there is no balancing system available. This will decrease the total capacity of battery packs more quickly during its operation and the battery system will fail permanently. Therefore, cell balancing methods are important for preserving the life of battery [1-9].

1.2 Problem Statement

Every cell in a battery pack is not equal to others in terms of its capacity or voltage or internal resistance due to the limitation of manufacturing technologies available. Over charging or over-discharging of cells in a battery pack is the result of imbalance in parameters and it affects the performance and lifecycle of the entire battery pack and worst of all that may cause a fire or explosion [1-9]. Therefore, it is necessary to employ a cell balancing scheme or equalizer, which is far more feasible and economical than developing new manufacturing technology, in order to eliminate the cell unbalancing. The two generalized methods of cell balancing are passive cell balancing and active cell balancing. It is important to study extensively the various topologies of passive and active methods of cell balancing.

1.3 Research Objectives

In accordance to the problem statement, cell balancing is very crucial and important function of battery management system (BMS). The objectives of the research are:

i. To study various passive and active cell balancing methods and simulate the selected active cell balancing schemes.

ii. To simulate Pack modularized active balancing topology using MATLAB/SIMULINK with following schemes;

- o To simulate Single Switched Capacitor (SSC) only Balancing method for balancing of cells in each module (Internal Module Balancing).

- o To simulate combination of Single Switched Capacitor, Auxiliary battery and Bidirectional DC-DC converter method for balancing of cells in each module and between modules.

- o To simulate a separate scheme for each module internal balancing using Single Switched Capacitor (SSC) scheme with Uni-directional converter.

iii. To compare and analyse the simulated balancing methods.

1.4 Scope of Work

There are a lot of cell balancing/equalization methods have been proposed in [1-20] and reviewed. The balancing topologies can categorize as passive and active balancing. The scope of this work includes,

- Focus on study of passive and active cell balancing.
- Focus on balancing system based on Pack Modularization.
- Focus on simulation of Single Switched Capacitor (SSC) and DC-DC Converter (Uni and Bi-directional) cell balancing topology only.
- Battery/ cell model is based on MATLAB/Simulink library.

In the first stage, cell balancing of the cells in a pack using Single Switched Capacitor (SSC) only balancing scheme is modelled. In the second stage, the balancing of each module using an auxiliary battery (AB), Single Switched Capacitor and a Bidirectional DC-DC converter is modelled and simulated. Also, a separate scheme for internal module balancing is studied using conventional SSC balancing with boost charging the capacitor via unidirectional DC-DC converter.

1.5 Project Outline

There are five chapters in this report, each providing discussions on different topics as outlined below;

Chapter 1: Introduction

This chapter introduces the basic concepts of Cell balancing system, its topologies and the importance of cell balancing system. The objectives and scopes are listed in order to give an overview of what the project is intended and its limitations.

Chapter 2: Literature Review

In this chapter, passive and active cell balancing topologies proposed by various researchers are elaborated in detail including its objectives, cell balancing speed, control complexity, size, advantages and disadvantages.

Chapter 3: Methodology

This chapter details schematic and design of Modularised cell balancing method and topology used of internal module balancing and module to module balancing. There are two methods studied for module internal balancing such as SSC only cell balancing topology and SSC with boost charging method. Also, this chapter details the schematic and design of Module to module balancing scheme using Bi-directional converter (BC) and auxiliary battery (AB).

Chapter 4: Results and Discussions

This chapter presents the comparison study of various passive and active cell balancing methods and its advantages and disadvantages. Also presents the results from simulation of SSC only balancing method, Module to module balancing using

BC and AB and SC with boost charging methods using MATLAB/SIMULINK are presented and results are compared in this chapter. The results of each simulation are discussed clearly based on the speed of balancing, maximum SOC differences and energy (Wh) transfer.

Chapter 5: Conclusions

Based on the results and discussions presented in Chapter 4, conclusions are drawn in this chapter. Also, future scope of works is also identified and presented here.

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