International Research Journal of Education and Technology
ISSN 2581-7795

Energy Management Strategy for Hybrid Energy Storage Systems for Pure Electric Vehicle Battery Management System

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Abstract

The most basic component in the electric vehicle is the battery that acts as a main source of energy and gives it mobility which is sustainable. In electric vehicles, the technology which is highly acknowledged and used for energy storage is based on Lithium chemistry. However, there is scope for research is still open. This includes the selection of the materials for cell manufacturing. The development of algorithms and designing of the electronic circuits for a better and effective utilization of the battery is also one of the areas of research. For optimal performance of the batteries, it is important to keep check on the vital operational parameters of the battery during the charging and discharging. A battery management system (BMS) is one such mechanism for monitoring of the battery internal and ambient temperature, current, voltage and controlling the charging and discharging operation. In this paper, some of the interesting approaches and system for battery management is discussed. The requirement for the state of art system for optimal battery performance and its general architecture is also discussed.

Keywords: Electric Vehicle, Lithium-Ion battery, battery management system, energy storage system.

1. Introduction

Lithium-ion technology based batteries are highly popular because of its merits like temperature sensitivity, lower volume, maintenance, high efficiency and small weight [1–3]. It is the most suitable source of power of the present century and has a prosperous and bright future in many applications, like electric vehicles (EVs) or any portable electronic devices [4]. When in use, the Electric vehicles (EVs) are very efficient in terms of energy utilization with zero–emission, thus making it very important factor in sustainable mobility. In Electric vehicles, driving range is most vital factor for determining the performance of the vehicle and it is mostly based on the battery of the vehicle. Thus, the technology used in the battery and its effective utilization is of utmost important while choosing the battery. In this modern world, Li-ion chemistry is the most popular battery technology utilized by the industry.

The main reason behind adapting the technology is charge/discharge efficiency in pulsed energy flow systems, high energy density and high power rating. To make a battery string with the required voltage (up to 400 V), a large number of Li-ion cells are connected in series, depending upon the application. Li-ion chemistry based batteries are very sensitive to deep discharge or overcharge problem. It may affect the battery like shortening the lifetime of the battery, and can even leads to dangerous situations. This thing generates the need for adapting the proper mechanism for battery maintenance. The Battery Management system is required to monitor and manage each cell of the battery within its reliable and safe operating range. Other than the main and basic function of maintained of the battery, the BMS should be able to monitor the status of the battery, so as to estimate the residual amount of energy it can deliver to the load. As the battery performance varies with respect to time, especially in terms of internal resistance and utilization capacity. Thus optimal monitoring of the battery becomes a challenging task.

One more important factor on which BMS needs to work is the solution for improving the battery life. The BMS should be able to manage the issue originated with unbalanced charging in the cells connected in series. This reducing the effect of this issue is necessary as it directly affects and degrades the usable capacity of the battery. This is so, because the cell having minimum charge determines the end of discharge. Even if the other cells of the battery still have energy stored in it, the entire battery gets discharged. Thus, avoiding the optimal utilization of the battery. This charge unbalancing issue is not self-recovered; rather it gets worse with the time. It happens because of the strict voltage limits applicable to Li-ion batteries.

Basically when one of the cells gets charged till its higher voltage limit, the charging of the battery must be stopped which causes the other cells not to be charged fully. If the entire cell is considered to have same capacity, the unbalancing of the charge leads to the different rate of discharge though, the mismatch in capacity is nearly limited to very little percent. This difference in capacity is also identified by a temperature gradient along the string of the battery. Thus, the BMS must tackle the issue of charge mismatching so as to restore the balance in energy utilization. There are various techniques discussed in the literature that presents the critical factors to identify the state of battery, so as to ensure that the battery gives its specified maximum output while optimizing the charge/discharge processes.

2. Literature Review

Solar-powered lithium batteries are used broadly. This innovation has pulled in more consideration, particularly for an electric vehicle, because of a perfect other option, local energy freedom, cost and reserve funds [5]. In Li- ion batteries, there are number of critical factors for example, sturdiness, dependability, and wellbeing that should be tended to in all ways of versatile implementations [6].

The Li-ion batteries have not just only the benefit of high power capacity and high density of energy but it has an unique ability and advantage of very low rate of discharging which is around 6 to 10 %, longer life cycle [7], high release current and terminal voltage, and also the non-memory impact. Also, if the Li-ion batteries are discharged partly even after charging, it will have no effect on the capacity availability because of the free of memory effect. As the Electric Vehicles has the requirement of high current and voltage, in such cases the Li-ion technology based batteries can be considered for the usage as it has the high voltage driving capacity in comparison to other rechargeable batteries.

To deliver the high current and voltage to the load in the application of "electric vehicles (EVs)" and "plug-in hybrid electric vehicle (PHEVs)", the pack of battery consisting of a high number of cells which are connected either in parallel (P) or series (S) connection is used [9]. These combinations of cells in the pack of battery configuration can be 1S2P, 1S3P and 2S2P [10, 11]. A battery pack of 13 modules with 2S2P is being used in IIUM electric vehicle. As per the studies presented in [12] [13], the most essential requirement for making an battery usable in electric vehicle industry are represented in the best "charge to weight" solution by this technology. It provided an easy replacement of Ni-MH based batteries. One more advantage of Li-ion is that of memory effect which not available here, ultimately resulting an improvised life cycle.

The pack of Battery is a non-straight framework, accessible limit is influenced by the inordinate temperature, under discharging, or over charging, and charging-discharging cycles. The pack of battery ought to be administered by battery the executive's framework so as to offer the safe activity and ideal way of execution [14]. At the end of the day, it gives suitable battery usage, ensured most extreme execution, observing present battery pack's condition and determination [15]. The Battery Management System basically works as a medium between various modules such as load and charging source of the system and the battery [16]. It also helps in improvisation in the performance of the vehicle and optimizing the operation in a safe manner.

The Battery Management System with software and hardware management must be consisting of the following parts: SOC estimation, thermal management, charges balancing, communication and charging, discharging. Practically, the BMS gathers all the essential data from the sensors like SOC, temperature, voltage and current connected to the pack of batteries and make a particular move by actuating the exact hardware during charging and releasing activity. The target of this article is to create remote battery the board framework to control the activity of evaporative warm administration framework to keep up the battery temperature $\leq 40°C$ and balance the SOC of the cells with the greatest variety of $(0.75 \pm 5\%)$ Ah.

Proper and Exact estimations for state of charge (SOC) has always been a crucial issue in the construction of BMS for EVs. Precise and efficient analysis is not only need for the evaluation of the durability estimation of a battery, but it also gives some crucial analytical data, such as the remaining useable time or energy [16].

SOC gives us the idea about the driving range of the vehicle or the remaining power of the battery in EVs. A battery management system (BMS) performs monitoring of the battery internal and ambient temperature, current, voltage and controlling the charging and discharging operation. In this way, precise SOC estimation of Li- particle battery is a precarious assignment since it can't be straightforwardly surveyed utilizing any physical sensor [17]. Currently, the Li-ion battery SOC estimation is an interesting issue for analysts. A combination of SOC estimation procedures has been accounted for throughout the most recent decade.

3. Building Blocks of A BMS

There are various Battery Management System available, either buy the available Integrated IC or even customize our own BMS and have three different types of BMS available. They are differentiated on the basis of their topology. The three available BMS are Modular BMS, Centralized BMS and Distributed BMS. Though they have different topology, there basic functionality and working is same. Following figure 1 shows the structure of generic Battery Management system.

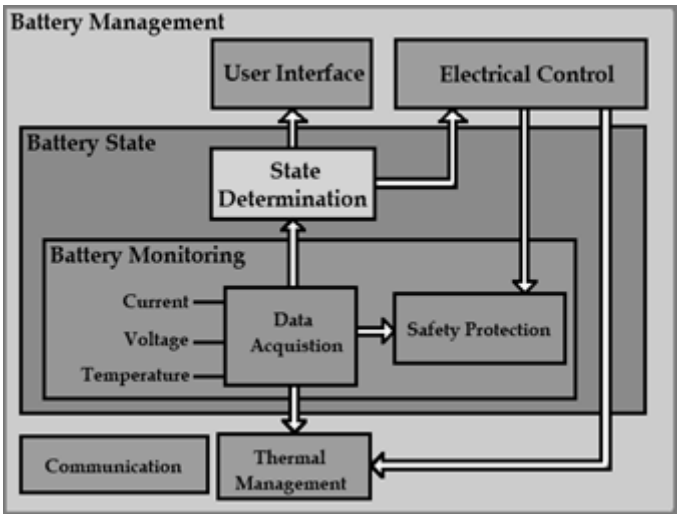

Figure 1 Block diagram of battery management system

The main use or functionality of the BMS is to monitor and analyses the three important parameter like temperature, voltage and current from each cell of the Battery. As discussed in the above section, the battery packs are formed using number of cells connected either in series or parallel configuration. If the cells are connected in parallel, the voltage only is usually measured, as it remains same across each cell. When the set of cells are connected in series, current for the complete series will be same in the circuit and need to measure voltage across each cell. In the figure 2 the cells are connected in series and in the circuit current is being measured for the whole circuit, whereas the temperature and voltage are measured for each cell.

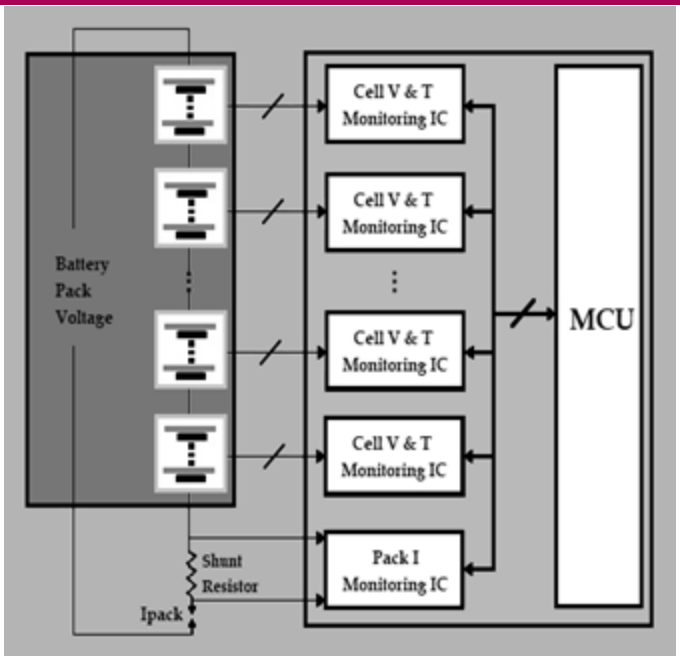

Figure 2 Connection of cells in series in BMS

4. Calculating Cell Voltage in BMS

As there are number of cells are connected in a typical EV, it becomes a complex and difficult task to measure the voltage of individual cell in a battery pack. Provide protection of the cell can be provided and perform cell balancing, only if the voltage for each cell measured. An ADC is used to measure the value of voltage for individual cell. As the batteries are connected in series the complexity involved in the measurement is quite high. This means that all the terminals across which the voltage needs to be measured will be changed every time and have number of ways to perform this which involves muxes and relays etc. Also there is also few IC like MAX14920 for battery management are available. These ICs can be used to measure the voltage of multiple cells that are connected in series for individual cell.

5. Calculating Cell Temperature for BMS

In Batteries, apart from temperature of the cell, the BMS needs to measure the temperature of the motor, and the bus temperature as everything here works on very high current. NTC is the most common element used for measuring the temperature of the BMS. NTC is the Negative temperature Co-efficient (NTC). It is basically similar to resistor except that it decreases its resistive capacity with respect to change in the temperature around it. By simply calculating the voltage across the device and applying the ohms law, the resistance of the circuit can be calculated, thus the temperature can be measured.

6. Calculating Pack Current for BMS

A very high value of current measuring up to 250A or even high can be drawn from the battery pack of the electric vehicle. To make sure that the distribution of the load is even amongst all the modules, needed to measure the current of each pack. While need to make sure while designing the elements for current sensing that there has to be an isolation between the current sensing and current measuring devices. The Hall-sensor based method and the Shunt method are the most commonly used current sensing methods. Both have there on advantage and disadvantages. Recently due to high precision rate availability the designs with shunts methods having modulators and isolated amplifiers are preferred more in comparison to hall sensor based approach.

7. Conclusions

In Electric Vehicles, the Battery Management System is the most critical and essential component. BMS assures the reliability and guarantees the safety of the battery and its operation. To maintain the reliability and assure the safety, the BMS must contain the functionality to calculate and monitor the cell balancing and charge controlling mechanisms. Battery is an electrochemical product, and thus acts differently under different environmental and operational conditions. The varying nature of a battery's performance makes it a challenge task to implement these functions. The evaluation of a battery state, which includes the state of life, state of charge, and the state of health, is an important task for a BMS. In this paper, the latest researches and technologies for the state evaluation and improved performance of the batteries are studied.

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