A BRIEF REVIEW ON BATTERY MANAGEMENT SYSTEM OF ELECTRIC VEHICLE

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Abstract : Electric vehicles are currently the best choice for transport in terms of efficiency, environment. The battery is a fundamental component of electric vehicles as it stores the electrical energy which is later used for traction purposes. A suitable battery management system (BMS) is the system which monitors various parameters of the battery to ensure that the battery operates in its safe operating area. BMS is vital in ensuring safe and reliable operation of batteries and even the life of the passenger depends on the battery system. An optimization of the BMS can allow an improvement on security of the vehicle, performance of the engine, energy optimization and extension of the battery life.This paper gives a brief review on schematic block diagram of battery management system and its components, its function like measurement of system voltage, current and temperature, the cells' state of charge (SOC), state of health (SOH), controlling and monitoring the charge/discharge, cell balancing, Thermal management. In this paper, a typical BMS block diagram has been proposed using various functional blocks. Also, it describes the various algorithms used to determine SOC and the flow of operation of BMS according to the mode of operation of the electric vehicle

Index Terms **– battery management system(BMS),State of charge(SOH),State of Health(SOH),Cell balancing, Battery temperature.**

I. INTRODUCTION

The battery management system is one of the most important components, especially when using lithium-ion batteries. Currently, three types of traction batteries are available: the lead-acid, nickel-metal hydride and lithium-ion batteries. The Lithium-ion batteries have proved to be the battery of interest for Electric Vehicle manufacturers because of its high charge density and low weight. Even though these batteries pack in a lot of punch for its size they are highly unstable in nature. It is very important that these batteries should never be over charged or under discharge at any circumstance which brings in the need to monitor its voltage and current. This process gets a bit tougher since there are a lot of cells put together to form a battery pack in EV and every cell should be individually monitored for its safety and efficient operation which requires a special dedicated system called the **Battery Management System(BMS)**. Also to get the maximum efficiency from a battery pack, we should completely charge and discharge all the cells at the same time at the same voltage which again calls in for a BMS. Apart from this the BMS is held responsible for many other functions which will be discussed in this paper.

Electric vehicles (EV) employ high-voltage (HV) battery packs with series-connected cells that require periodic cell balancing for safe operation of the pack, requiring an effective battery management system (BMS) to maintain the battery cells in an operational condition while providing the necessary power efficiently. Battery management systems (BMS) make decisions on charge/discharge rates on the basis of load demands, cell voltage, current, and temperature measurements, and estimated battery SOC, capacity, impedance, etc. BMS is nothing but set of blocks performing various activities which monitiors and regulate the activities of battery in accordance to the need of the system or device. This will definitely improve the efficiency of battery pack and also make the battery powered system or device ever reliable.

II. BATTERIES IN ELECTRIC VEHICLES

Electric-vehicle batteries differ from starting, lighting, and ignition (SLI) batteries as they are designed to give power over sustained periods of time. Deep-cycle batteries are used instead of SLI batteries for those applications. Batteries for electric vehicles are characterized by their relatively high power-to-weight ratio, specific energy and energy density; smaller, lighter batteries reduce the weight of the vehicle and improve its performance. Compared to liquid fuels, most current battery technologies have much lower specific energy, and this often impacts the maximal all-electric range of the vehicles. However, metal-air batteries have high specific energy because the cathode is provided by the surrounding oxygen in the air. Rechargeable batteries used in electric vehicles include lead–acid ("flooded", deep-cycle, and VRLA), NiCd, nickel–metal hydride, lithium-ion, Li-ion polymer, and, less commonly, zinc–air and molten-salt batteries. The most common battery type in modern electric cars are lithium-ion and Lithium polymer battery, because of their high energy density compared to their weight. Table 1 illustrates some key characteristics for these popular battery types.

Battery Type	Service life /Cycle	Nominal voltage/v	Energy density /(W.h.kg^-1)	Power density /(W.kg^-1)	Charging effinciency	Self-discharge /(%.month^-1)	Charging Temp/C	Discharging temp/C
Li-ion Battery	600-3000	3.2-3.7	100-270	250-680	80-90%	3-10	0 to 45	-20 to 60
Lead acid Battery	200-300	2.0	30-50	180	50-95	5	-20 to 50	-20 to 50
NiCd Battery	1000	1.2	50-80	150	70-90	20	0 to 45	-20 to 65
NiMH Battery	300-600	1.2	60-120	250-1000	65	30	0 to 45	-20 to 65

Table 1 Popular types of battery in EVs

It is clearly shown that Li-ion battery is significantly better than other types of battery, especially in terms of large cycle life which is key to long service of EVs (e.g., 6–10 years' service life). Besides, lithium-ion battery requires almost no maintenance during its lifecycle, which is an advantage that other batteries do not have. No scheduled cycling is required, and there is no memory effect in the battery. Li ion become popular and remains the best choice for rechargeable batteries. Furthermore, the lithium-ion battery is well suited for electric vehicles because its self-discharge rate is less than half of the discharge rate of lead-acid and NiMH batteries. Despite the advantages of lithium-ion batteries, they also have certain drawbacks. Lithium ions are brittle. To maintain the safe operation of these batteries, they require a protective device to be built into each pack. This device, also referred to as the battery management system (BMS), limits the peak voltage of each cell during charging and prevents the cell voltage from dropping below a threshold during discharging.

III. STRCTURE OF BMS

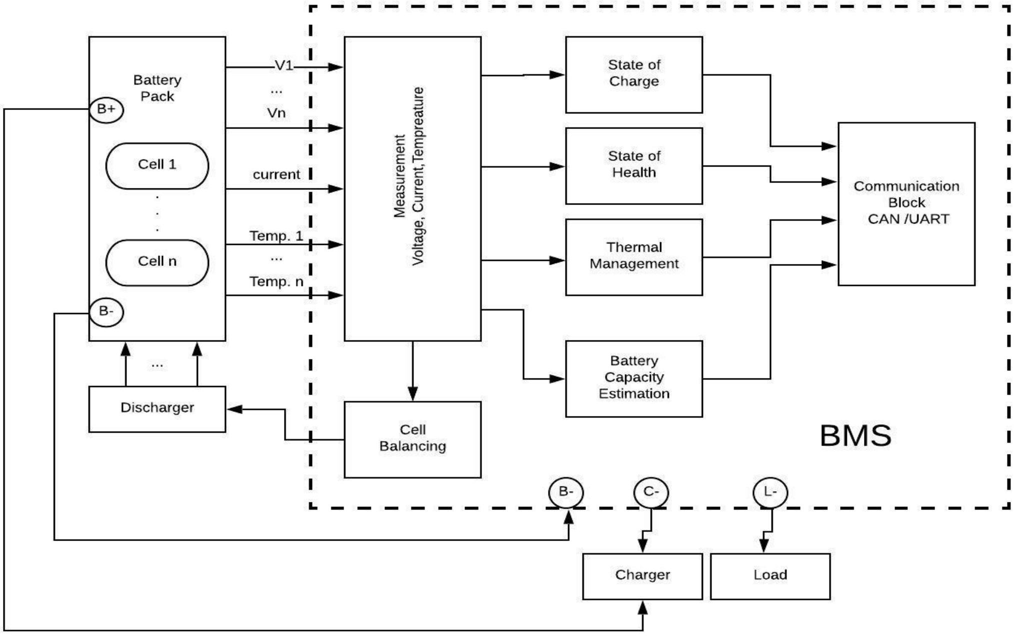

Fig. 1 Structure of BMS

3.1Charging & discharging control

Over-charging and over-discharging are two of the prime causes of battery failure and the BMS must maintain the cells within the desired DOD operating limits. Batteries are more frequently damaged by inappropriate charging than by any other cause. Therefore, charging control is an essential feature of the BMS. For lithium-ion batteries, a 2-stage charging method called the constant current – constant voltage (CC-CV) charging method is used. During the first charging stage (the constant current stage), the charger produces a constant current that increases the battery voltage. When the battery voltage reaches a constant value, and the battery becomes nearly full, it enters the constant voltage (CV) stage. At this stage, the charger maintains the constant voltage as the battery current decays exponentially until the battery finishes charging. The primary goal of a BMS is to keep the battery from operating out of its safety zone. The BMS must protect the cell from any eventuality during discharging. Otherwise, the cell could operate outside of its limitations.

3.2 SOC

The SOC refers to the remaining capacity (*Q*rem) as a percentage of the maximum available capacity. 100% stands for the battery is fully charged to its total capacity, and 0% stands for battery is fully discharged. Accurate SOC estimation plays a vital role in monitoring existing capacity state, to further guarantee the safe and healthy operation of battery. The SOC could signal the user and control the charging and discharging process. There are three methods of determining SOC:

1. Through direct measurement: To measure the SOC directly, one could simply use a voltmeter because the battery voltage decreases more or less linearly during the discharging cycle of the battery.
2. Through coulomb counting: In the coulomb-counting method, the current going into or coming out of a battery is integrated to produce the relative value of its charge.

3. Through the combination of the two techniques: In addition, the two methods could be combined. The voltmeter could be used to monitor the battery voltage and calibrate the SOC when the actual charge approaches either end. Meanwhile, the battery current could be integrated to determine the relative charge going into and coming out of the battery.

Several studies have been conducted to remedy to the problem of accurate estimation of the initial SOC. The most common technique is to use an OCV-SOC function that relates the open circuit voltage to its corresponding SOC value. In this proposed algorithm, we start by determining the SOC from measuring the initial OCV, for that we consider the inverse function noted SOC-OCV relationship of Li-ion battery which can be approximated to piecewise linear curve. This curve is actually determined experimentally by the OCV test by applying a pulse load on the Li-ion battery, then the battery reach equilibrium where the voltage is extracted in every 5% of Depth of Discharge (DOD).

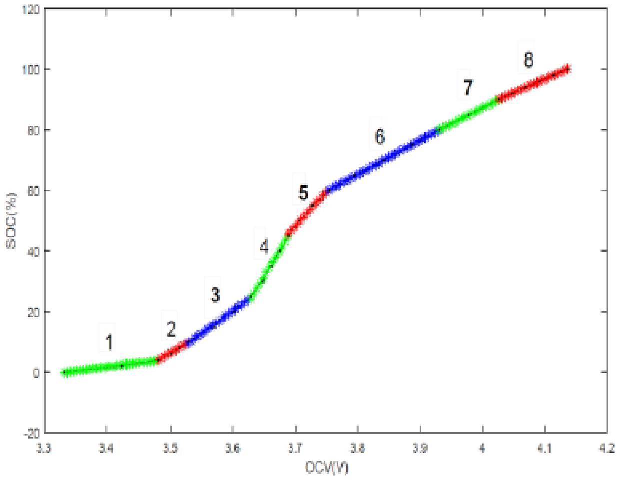

Fig.2: - SOC-OCV relationship

For each segment we are varying coefficients a and b according to OCV intervals. The coefficients for each segment are given in Table, with their voltage range.

Voltage Range (V)	[3.3; 3.452]	[3.452; 3.508]	[3.508; 3.595]	[3.595; 3.676]	[3.676; 3.739]	[3.739; 3.967]	[3.967; 4.039]	[4.039; 4.132]
a	26.55	125	149	344	229.5	111.9	104.8	90.61
b	88.6	431.1	516.1	1225	800.9	359.9	332	274.7

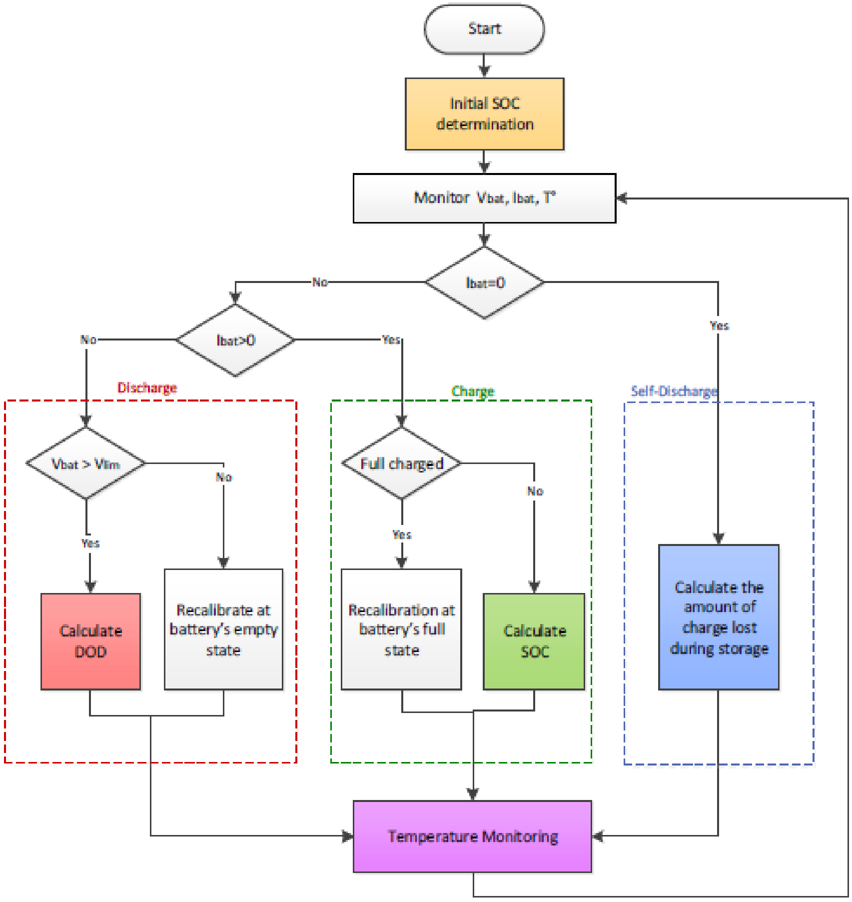

Fig.3: - SOC Calculation Algorithm

3.3 SOH

The maximum capacity on the battery (expressed in mAh) decreases every time the battery is recharged. The SOH is defined as the actual capacity of the battery normalized to the initial capacity.The SOH gives an estimation of the general health condition of the battery, with respect to its nominal performances. The SOH gives an idea about how good the battery still is, and whether itis time to buy a new one. Any parameter such as cell impedance or conductance that changes significantly with age could be used to indicate the SOH of the cell.

3.4 Cell Balancing

Cell balancing is a method of compensating weaker cells by equalizing the charge on all cells in the chain to extend the overall battery life. In chains of multi-cell batteries, small differences between the cells due to production tolerances or operating conditions tend to be magnified with each charge-discharge cycle. During charging, weak cells may be overstressed and become even weaker until they eventually fail, causing the battery to fail prematurely.To deal with this problem the BMS has to implement something called cell balancing. There are many types of cell balancing techniques, but the commonly used ones are the **active and passive type cell balancing**. In passive balancing the idea is that the cells with excess voltage will be forced discharge through a load like resistor to reach the voltage value of the other cells. While in active balancing the stronger cells will be used to charge the weaker cells to equalize their potentials.

3.5 Thermal Management

Battery temperature is another key factor to affect the battery performance in many ways such as lifetime, energy conversion efficiency, reliability and safety. Being the battery pack performances strongly related to the temperature, it is fundamental to keep the temperature of each cell of the battery and whole battery pack under control and activate heaters or coolers to maintain the temperature under defined limits. This action is performed by the thermal management block.

Surface temperature is easy to be measured directly using suitable thermal sensors or thermocouples. But internal temperature of battery is an internal state which is difficult to be measured directly. The difference between battery surface and internal temperatures would be quite significant (e.g., sometimes greater than 12 °C in high-power applications). Overheated internal temperature will accelerate battery aging and even lead safety problems such as fires and explosion. Therefore, measuring battery surface temperature is insufficient to protect battery. Proper estimation approaches of internal temperature are capable of not only preventing battery against damages, but also allowing BMS to make reasonable strategies to save energy.

3.5 Voltage and Current Measurement

EV has a large number of cells connected together, it is a bit challenging to measure the individual cell voltage of a battery pack. But only if we know the individual cell voltage we can perform cell balancing and provide cell protection. To read the voltage value of a cell an ADC is used. But the complexity involved is high since the batteries are connected in series. Meaning the terminals across which the voltage is measured has to be changed every time. There are many ways to do this involving relays, muxes etc. Apart from this there is also some battery management IC like MAX14920 which can be used to measure individual cell voltages of multiple cells (12-16) connected in series. EV Battery Pack can source a large value of current upto 250A or even high, apart from this we also have to measure the current of every module in the pack to make sure the load is distributed evenly. While designing the current sensing element we also have to provide isolation between the measuring and sensing device. The most commonly used method to sense current are the Shunt method and the Hall-sensor based method. Both methods have their pros and cons. Earlier shunt methods were considered less accurate, but with recent availability of high-precision shunts designs with isolated amplifiers and modulators they are more preferred than the hall-sensor based method.

3.6 Communication

The communications function of a BMS may be provided though a data link used to monitor performance, log data, provide diagnostics or set system parameters. The function may also be provided by a communications channel carrying system control signals. The choice of the communications protocol is not determined by the battery; instead, it is determined by the application of the battery. The BMS used in electric vehicles must communicate with the upper vehicle controller and the motor controller to ensure the proper operation of the vehicle. There are two major protocols used by the BMS to communicate with the vehicle: through the data bus or the controller area network (CAN) bus. Most BMS systems incorporate some form of communications between the battery and the charger or test equipment. Some have links to other systems interfacing with the battery for monitoring its condition or its history. Communications interfaces are also needed to allow the user access to the battery for modifying the BMS control parameters or for diagnostics and test.

IV. MODES OF OPERATION

The operation of an electric vehicle can be primarily divided into three categories viz, charging, idle, propulsion. Based on these the functions implemented by the BMS during each mode of operation of electric vehicle are different. Based on this we can divide the modes for BMS as

A) Charging: - In this mode, the continuous monitoring of individual cell voltages, total pack voltage, temperature needs to be done. During charging process there is a possibility that the pack may overheat and this is prevented by monitoring temperature using a NTC type thermistor. The output of thermistor is fed to the Arduino where it is monitored and if it is beyond permissible limits then the charging process is stopped. Similarly, overvoltage is determined using outputs of Op-amps and if required necessary course of action is taken. During this mode, the SOC calculation also needs to be carried out so that user will know the exact capacity of the battery pack. After the charging mode preferably the process of Cell balancing needs to be carried out to ensure the voltages of all cells are equal to the voltage of the weakest cell so that the there is not undue stress on it.

B) Discharging: - The processes carried out in this mode are similar to the ‘Charging Mode’. The voltage of individual cells and the battery pack are to be continuously monitored to prevent the discharge a cells below a certain threshold value. Also, temperature needs to be measured to prevent overheating. The SOC is calculated to let the user know how much battery capacity is remaining so as to estimate the distance range that can be covered. Also, the pack’s discharging process is stopped if the SOC value goes below a certain value because if battery discharges below a certain limit the battery cannot the recharged again. After the discharging mode, cell balancing must be carried out to ensure that battery does not degrade at a faster rate.

C) Normal: - This mode is active when the pack is neither charged nor discharged i.e. the vehicle is in standstill state. During this mode, the most important function carried is cell balancing. The voltage of the weakest cell in the battery pack is lowest. The voltages of other cells are higher than this cell. Using a switching device which is controlled by Arduino, the extra voltage is dissipated across an external bleeding resistance. Also, during this mode the individual voltages of cells are measured which are used in SOC determination. This mode needs to be carried between every charging and discharging cycle.

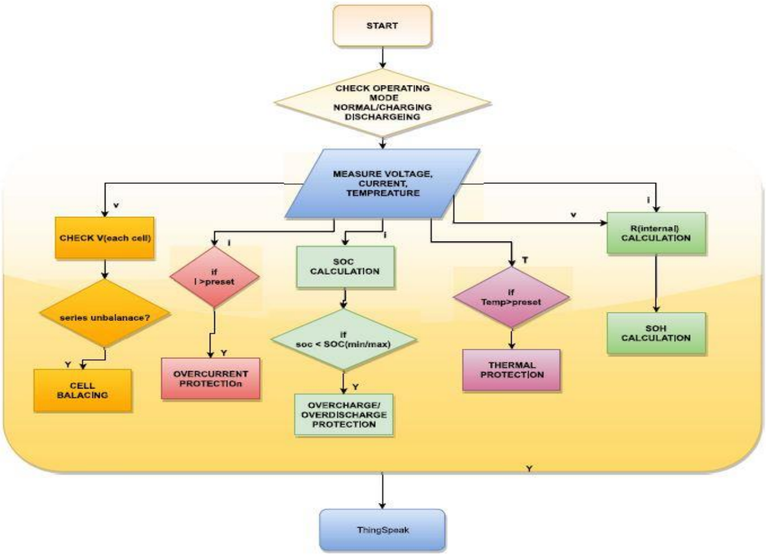

Figure 4

V. REVIEW OF BMS IC’S

Effective battery management is becoming vital as portable applications are widening. Many industries have started manufacturing the BMS ICs which will perform various operations which as discussed above.

[1] Maxima integrated products many low cost and reliable battery management ICs. Among them are MAX77301, which provides the charge control specially designed for Li based batteries. DS2775 will provide information on charge remaining along the battery protection feature.

[2] Linear Technology, now part of Analog Devices , has wide range of ICs which provide different features of BMS as discussed above in various section for different types of battery chemistry.

[3] Texas Instruments also provide wide variety of BMS ICs for various applications ranging from personal applications to industrial and automotive applications.

VI. CONCLUSION:

This paper gives review on measurement of cells voltage, battery temperature, battery voltage and battery current. It introduces one method that uses specific IC to measure Li-ion battery cells voltage, battery temperature and cells balancing, which is more simple and practical, cost-saving and more precise. Besides, this paper gives a review on popular batteries in EVs.

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