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A Novel Battery Management System for Series Parallel Connected Li-Ion Battery Pack for Electric Vehicle Application.

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Abstract: ***The green energy evolution initiated the use of electric and hybrid electric vehicles at present on roads. These vehicles extensively use different types of batteries and among them lithium ion batteries are prominent. The Li-ion battery pack constitutes number of Li-ion battery cells connected in series and parallel configuration. This battery bank needs a suitable battery management system for its efficient operation. This paper presents a novel battery management system to monitor and control the battery current, voltage, state of charge and most importantly the cell temperature. The detail BMS scheme for Li-ion battery pack is presented and simulation is carried out to validate its performance with a driving cycle of electric car.***

Keywords: Lithium-Ion Battery, BMS, Electric Vehicle, MCU.

I. INTRODUCTION

Among the different batteries available in market, Li-ion batteries are one of the most advanced rechargeable batteries attracting much attention now a day. Currently they are the leading mobile power sources for portable electronic devices, entirely used in cell phones and laptop computers [1]. Also the increasing functionality of mobile electronics always demands for better Li-ion batteries for high power application like in smart grid area, railway. Another important market for Li-ion battery is electric vehicles which is expanding rapidly needs next-generation Li-ion battery with high energy density, high power density high charging rate, long life, high capacity, improved safety performance and low cost. For these applications large amount of power and energy are required from Li-Ion battery therefore a battery management system (BMS) is required with essential functions like cell balancing, SOC estimation, prediction of available power to operate the batteries efficiently [2].

Now days we find large use of Li-ion battery heavily in different applications particularly used in mobile phones, laptops and in many other areas. The present technology is suitable for low power application where as for high power application lots of improvements are required to meet the power requirements. Intensive research and involvement of many researchers are required to meet the increasing power demand particularly for electric vehicles, to develop next-generation Li-ion batteries with significantly improved performances, including improved specific energy and volumetric energy density, recyclability, charging rate, stability, and safety. There are still many important challenges in the development of next-generation Li-ion batteries.

Lithium ion batteries are commonly used in electric vehicle application because they have high energy density and are light weight as compared to lead acid batteries which contains heavy lead plates with an acid electrolyte [3]. Even though li-ion batteries are more suitable and have more advantages, they need high test condition and protection during manufacturing to avoid accidents and failure [4].

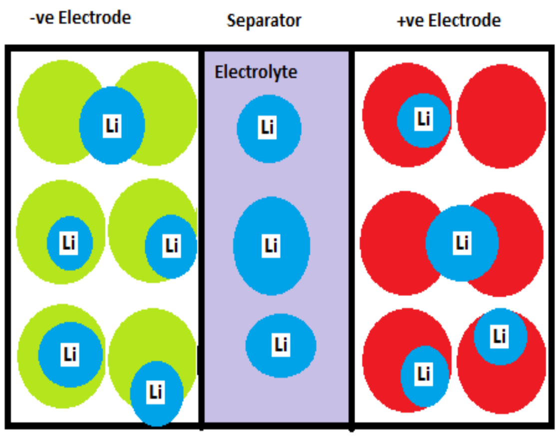

Fig.1 Lithium-Ion Battery structure.

As mentioned Li-ion battery consists of two electrodes such as anode and cathode and are separated by an electrolyte is shown in Fig.1. During charging ions move from cathode to anode and during discharging they flow from anode to cathode.

A high power Li-ion battery is formed by connecting many Li-ion cells in series and parallel to increase voltage and current respectively. A battery module is formed by integrating many battery cells. Multiple battery cells can be integrated into a module. In case of using for electric car a battery pack of 85 kWh contains 7104 cells to form an efficient battery module.

Typically, a Li-ion battery cell consists of a positive electrode known as cathode and a negative electrode as anode and their reaction takes place through an electrolyte containing lithium ions.

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The electrodes are separate through a polymer membrane, which allows the exchange of lithium ions between the two electrodes.

Figure 2 illustrates the basic characteristic of a distinctive Li-ion battery cell. Due to the electrochemical reaction between the two electrodes, the stored chemical energy is released [5]. The Li-ion battery performance is evaluated by many parameters, such as specific capacity, volumetric energy, specific energy, recyclability, safety, tolerance, and rate of charging and discharging. Specific energy is the indication of the amount of energy which can be stored in the battery and released during its use per unit mass of the battery. It is achieved by multiplying the battery operating voltage and specific capacity (Ah/kg). The amount of charge which is stored per unit mass is known as specific capacity of the battery. The life of a lithium ion battery depends on depth of discharge (DOD) in cycle basis and temperature rise within the cells during its operation [6]. Appropriate safety and power management is very much required for Li-ion batteries with multiple cells. Battery management systems (BMS) are essentially employed for battery banks to avoid likely thermal runaway. In any abnormal operation, if any cell fails inside a battery pack, the BMS can detect easily and indicates to isolate the particular cell.

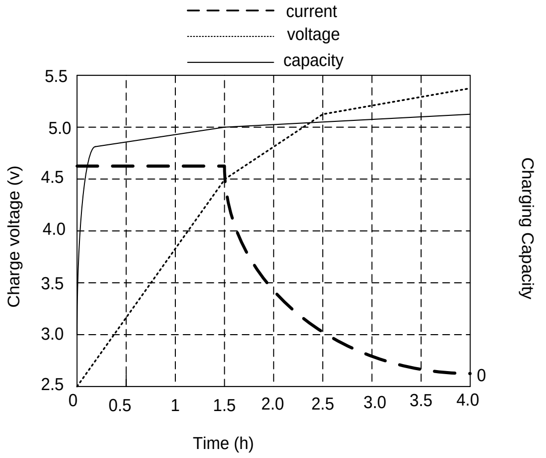

Fig.2 Lithium –Ion Battery Characteristics.

II. BMS CONFIGURATION

In electric vehicles, battery pack consists of many cells connected in series and parallel depends on the design of the engine [7]. It is a challenge in terms of life span of battery, safety, performance, charging characteristic for the designers to provide more sustainable and adaptable power supply for use in electric vehicles. The microcontroller unit is the heart of the BMS which manages various functions of the different devices connected in the circuit [8]. The intelligent monitoring system provides the battery information during charging and discharging of the cells and helps the user to supplement the information to control the system. It provides the information about the internal damage of the cells. Battery may fails if the cells suffer from thermal run away which affects other devices in the system may lead to failure also [9]. The monitoring system also assigned to show the battery voltage, current and temperature of the cells. The data is required to send to control unit to have proper action under various situation of the drive. The micro controller unit is a multitasking device performs many critical actions depending on the complexity of the vehicle design and requirements.

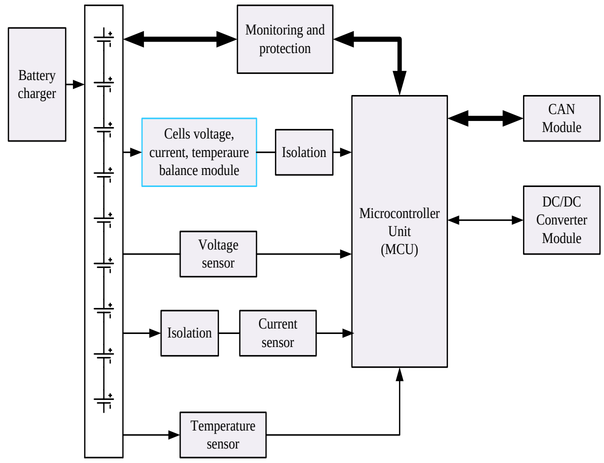

Fig. 3. Battery Management system configuration.

The robustness of the proposed BMS is verified through computer simulation using simulink platform which is tested by using it with an electric vehicle for a complete driving cycle including variable speed command and regenerative braking action. The BMS structure is shown in Fig.3. The overall design is based on the communication between the devices connected in the BMS circuit. All the devices are connected through CAN bus. The most important parameters need to be monitored and control in this BMS are battery voltage, instantaneous current, Battery State of charge (SOC) and cell temperature. The microcontroller based control makes the control task easy in many ways but where the control involves intense mathematics, the Digital signal processing (DSP) is more suitable and widely use processors include Texas Instruments (TI) C28x core series of micro controllers [9]. The BMS ensures performance of the battery pack and its life span with the help of microcontrollers.

A separate charging circuit is used for safe and quick charge of cells and the controller should ensure that the cell voltage should not increase the rated voltage of the cells which is monitored continuously. Efficient charging and discharging of battery is important to avoid thermal runaway [10]. It is essential to acquire real time response from all components for real time system particularly when vehicle operates at higher speed. The data monitoring, sending and microcontroller action should be done at a higher frequency also to cope with the sudden change in speed, load and other control parameters. Hall Effect sensors can be used to measure the currents of cells which simplify the design procedure. For SOC estimation, ampere hour calculation is required and the following equation (1) is used to calculate Ah. The battery energy is calculated using equation (2).

$$A_h = \int I_T(t)dt = \sum_{n=1}^{m} I(t).dt \qquad (1)$$

$$E_{Bat} = \int P_T dt = \int V_t I_t dt \qquad (2)$$

III. IMPLEMENTATION AND DESCRIPTION

The proposed battery management system is designed based on the functional operation of a real vehicle.

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In this present case four Li-Ion batteries of equal ratings are taken as main power source of the vehicle.

The simulation is carried out to observe the BMS performance when fault happens in one of the cells. The BMS intelligently identifies the faulty battery and subsequently send the essential information to the driver for monitoring and necessary action. The battery voltage, current and state of charge of the four cells are analyzed and are presented in this section. The current status of all four cells are continuously accessed by BMS and it is found that out of four cells one cell (cell no-3) is faulty and the information is processed through the micro controller and instructs the user for repair or replacement of the faulty battery. It is observed from fig.5 that cell-3 produces less amount of current which is far deviated from the desired current command. All the cells in the battery pack should share equal amount of load current under healthy condition. Faulty cells also affect the performance of other components of the system. Immediate replacement is inevitable for reliable operation of the system. The defective cell does not respond to the charging process and other healthy cells receive the charging current to charge in minimum time as depicted in fig.6. Charging and discharging of good condition cells and the defective cell are shown in Fig.6 (a) and Fig.6 (b) respectively. Fig 7 shows the current sharing of all the four cells to the load considering healthy condition of cells. The sharing of currents are among the cells are exactly equal almost free from errors. This proves the satisfactory performance of the battery management system. Similarly Fig.8 shows the battery state of charge after clearance of the faults with charging and discharging phenomena and the results indicates the accuracy among the cells behavior.

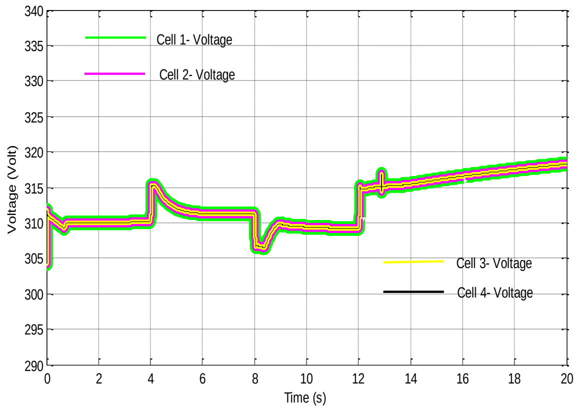

Fig.4 Battery terminal voltages (Four Cells).

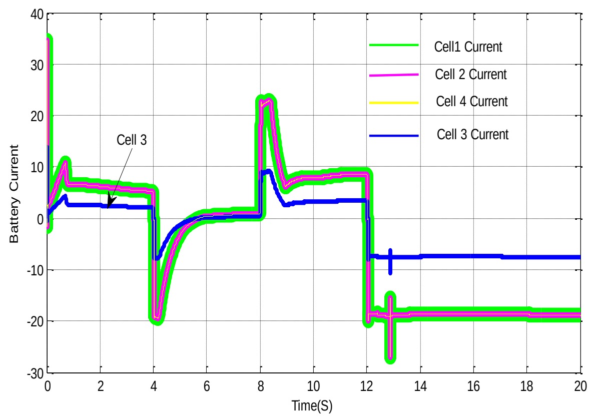

Fig. 5. Battery Currents (Green-Cell1, Pink- cell 2, Blue- cell 3, yellow- cell 4).

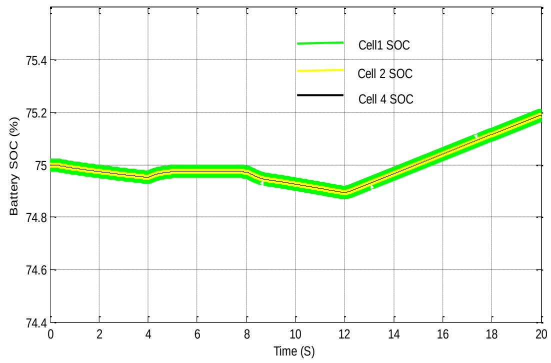

Fig. 6(a). Battery SOC (Green-Cell1, Pink- cell 2, yellow- cell 4).

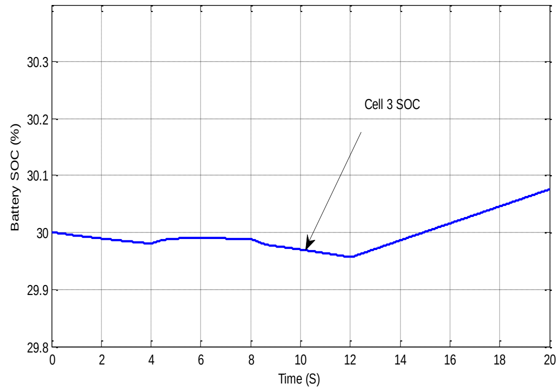

Fig. 6 (b). Battery SOC of Cell3 (Defective)

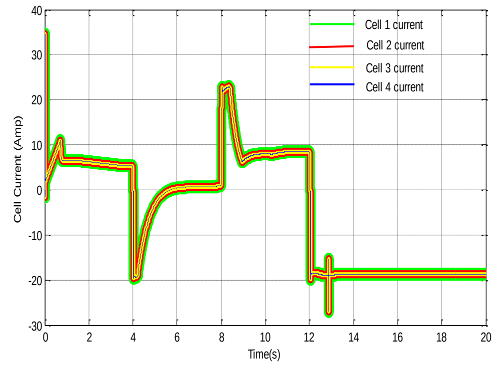

Fig. 7. Battery Current of Cells after clearance of fault.

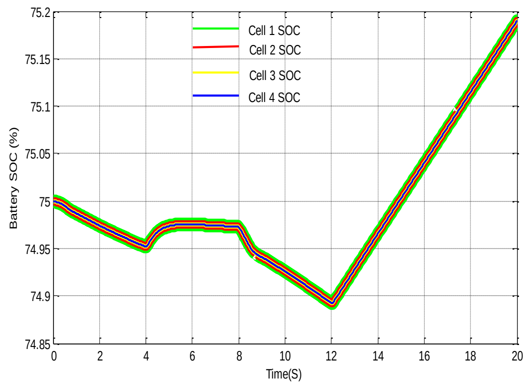

Fig. 8. Battery SOC of all Cells after clearance of cell 3 fault

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IV. CONCLUSION

The novel battery management system for lithium ion battery pack is presented in this paper. This scheme is demonstrated with a faulty battery condition. The BMS proves to be very effective in identifying the abnormal operating condition cells which enables the user to recognize the faulty battery easily. The status can be monitored on the display unit connected to the microcontroller. The proposed BMS broadly does the function of power management, displaying of real information of cells and also protects the battery from over current, over voltage and temperature rise. It is observed that the battery management scheme can be implemented in real time application to reduce the complexity associated with battery powered electric vehicles and hybrid electric vehicles.

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Premananda Pany Ph.D in Electrical Engineering with specialization Power electronics & drives from MNNIT, Allahabad. Currently working as Associate Professor in EEE Department at Sharda University. Have 17 years of experience in the field of Teaching, Research & Industry. Published research papers in the area of Power Electronics, Electric vehicle in various international journals and conferences.