A Review on Battery Management System for Electric Vehicles

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Abstract— A battery management system (BMS) is an electronic regulator that monitors and controls the charging and discharging of rechargable batteries, keeping a check on the key operational parameters during charging and discharging such as voltages, currents and the battery internal and ambient temperature. The monitoring circuits would normally provide inputs to protection devices which would disconnect the battery from the load or charger any of the parameters like overcharge,undercharge,high temperature,become out of limits. The battery management system (BMS) is a critical component of electric and hybrid electric vehicles. The purpose of the BMS is to guarantee safe and reliable battery operation. To maintain the safety and reliability of the battery, state monitoring and evaluation, charge control, and cell balancing are functionalities that have been implemented in BMS.

Index Terms—

1 INTRODUCTION

Transport sector dependent mostly on oil and fuel, which their prices are unstable and their reserves are severely depleted. Moreover, the use of these forms of energy pollutes the environment and causes the emission of greenhouse. Much research has been interested by the economic efficiency of the integration of electric vehicles. They present an overview of the impact of the increasing penetration of the EV into vehicle market. Focusing of the electricity system and the emergence of vehicle to grid technologies, batteries and EV recharge infrastructure conclude the need for standardization to facilitate safe transition with economically efficient and environmentally abiding. And estimate costs of plug-in electric vehicles and their work shows the advantages of smart electric vehicles compared to the dumb electrical vehicles which that appear most in timing of charging and discharging of EVs. To improve vehicle performance various researches deal with the optimization of energy management for the new generation of vehicle Battery is one of the energy storage management systems in HEV or EV. The battery provide power when vehicle accelerating and absorb power when vehicle braking. So the cruse range and accelerate performance depend on the battery. Usually, there is a battery management system (BMS) in battery pack of vehicles. The BMS monitor the statues of the battery, and communicates with vehicle control unit(VCU), to ensure the battery not in abused, such as over-charged, over-discharged or over-temperature. And BMS play a vital role in hybrid and electric applications, since the importance of BMS have a significant impact on the energy efficiency and the battery's life.

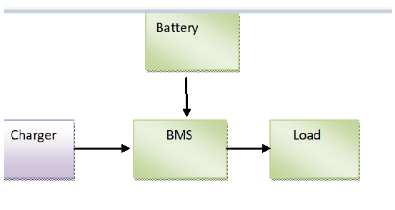

Fig.1. Block diagram of BMS

2 METHODOLOGY

A battery management system is used to ensure the optimum use is made of the energy inside the battery and to minimize the risk of damage inflicted upon the battery. This is achieved by monitoring and controlling the battery's charging and discharging together with working temperature. The function of a BMS can be divided into the following tasks.(see fig.2)

A. Data acquisition
B.Battery state determination
C.Electrical management
D.Thermal management
E.Safety management
F. Communication

The design of a battery-powered vehicle requires many battery-management features, including charge/discharge control, battery-capacity monitoring, remaining run-time information, charge-cycle counting. These features not only affect the performance of the battery pack and the reliability of the EVs, but also affect the cycle life (the number of cycles that a cell or battery can be charged under specific conditions, before the available capacity in ampere hour(Ah) fails to meet specific performance criteria.) of the cells. To achieve the goal of monitoring and controlling the battery's charging and discharging together with the working temperature, The system is divided into 5 main parts, which is consists of a current analyzing and State of charge/State of health (SoC/SoH) estimating module complex fast acting energy management system (CASM) where the current is handled and the SoC/SoH of the cell is estimated, a Voltage temperature analyzing module (VTAM), which gets the data collected by the DPs sampling circuits and carries out further analyzing, a MOS control module, which is used to control the turn on/off of the battery to keep it in security, a display module is introduced to display the current, voltage, temperature, SoC, SoH, remaining time of the battery to the users, and a battery pack, which has been separated into several small parts. As there are hundreds of cells need to be monitored, in this BMS,model the battery pack has been cut into small subpacks with much less cells in each sub-pack, which made the controlling and monitoring of the cells in each sub-pack much more conveniently. (see fig.3)Each module in VTAM works independently, getting the data sampled by each IC embedded in each sub-battery-module, sending them to the CASM through the data bus after analyzing, and in-forming the monitoring its state (MOS) controller through the direct channel to microchip (MC) when there is any emergency, which ensure timely response could be made to any aberrant.

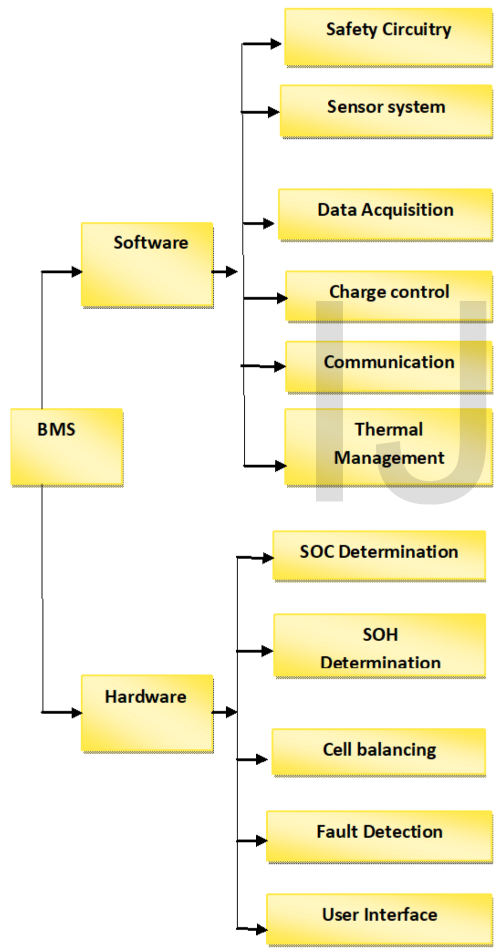

Fig.2. System architecture

3 Design of BMS

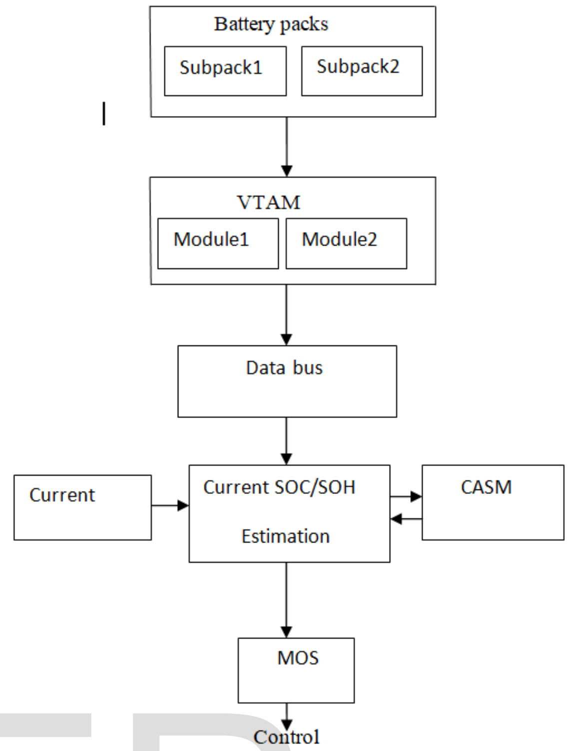

Fig.3. Structure of BMS

The working temperature and voltage data sampled by the ICs integrated in the battery pack will be sent to the Voltage and temperature analyze modules (VTAM) when commands are sent to them (see fig.3). After analyzing in the VTAM, a signal will be sent to the MOS controller if the temperature or voltage of any cell is out of the allowed range. And then, the MOS controller will start the protect circuit to keep the battery out of danger. Similarly, the current sampled by the current sampling module is analyzed in the complex fast acting energy management system (CASM) where SoC, SoH and remaining working time estimation take place. The MOS control will immediately function the protect circuit to get rid of any danger. The temperature and voltage data of each cell are also sent here through the communication channel. At last, the character parameters of each cell will be displayed on the display module. In case of emergency, the module in VTAM gives a signal to the MOS controller immediately to prevent any cause to the battery through the channel between the VTAM and the monitoring it state (MOS) controller. Without this channel, any emergency detected by the module in VTAM should firstly be sent into the CASM, and then be sent into the MOS controller after analyzing, which would greatly delay the response made to the emergency.

3.1 Voltage and Temperature Sampling Module (VTSM)

Each sub-pack, composed of hundreds of cells in series or parallel connection and another module to power the sampling module (SM),(see fig.4) has its independent sampling module,the management of all the cells in the sub- pack is much more reliable and efficiency, with the security and reliable improving.

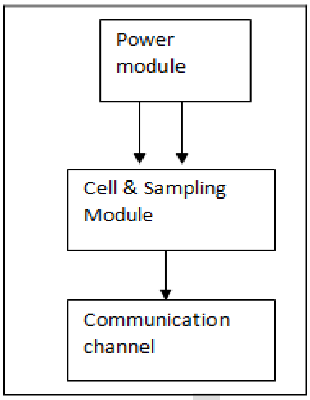

Fig.4. Structure of one subway pack

The power module powers the SM integrated in each sub-pack. The SM can real-time sampling the parameters of each cell, including cell voltage, cell temperature and the environment temperature.After analyzing the sampling data, the ICs can decide whether the balancing circuit should take effect. Afterwards, the data are sent to upper monitoring control unit (MCU) through the communication channel when a command is received.

3.2 Balancing Circuit

Due to the differences in technology, parameters, chemical composition, manufacturing procedures, self-discharge, and inconsistent with the aging curve, not all the batteries simultaneously get full charged during charging or discharge at the same level.(see fig.5) The performances are different among cells. 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**. 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. The SoC of different cells in th series may be different both during charging and discharging. During charging, one cell may have been fully charged, while the other may have not. If continuing charging, the fully charged battery will be overcharge and this may cause a fatal damage to the cell which will greatly shorten the life cycle of the cell, even a catastrophe to the whole battery pack may occur. If stopping charging, the one has not be fully charged shortens its charge and discharge cycles (CDCs).used to describe the number of charge-discharge cycle of a cell before the available capacity in [Ah] fails to meet specific performance criteria, is an important parameter for a cell And vice versa. So, a reliable and efficiency BMS design must include a balancing circuit for each cell. In our design, a balancing circuit (BC) is employed aside each cell.

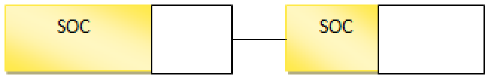

Fig.5. Differences in same series cells

3.3 Current Sampling Module(CSM)

Current is an indispensable parameter for a cell's controlling and monitoring.The ordinary Soc estimation methods, like coulomb counting and Kalman filter algorithm, use current as an important parameter. Besides, the higher the current is in the battery pack, the more heat will be produced by the cells, which will directly rise the temperature in the pack. If the heat cannot be released timely, the result is burdensome. In order to avoid the temperature in the battery pack runs too high, it's necessary for the BMS to monitor each cell's temperature. The current sampling module designed in our BMS consists of a current sensor module and an amplifying module.The output signal Current is sent into the Current Sampling Module, and further analyzing is carried(see fig.6) The reliability and precision of the current sensors are much more determined.

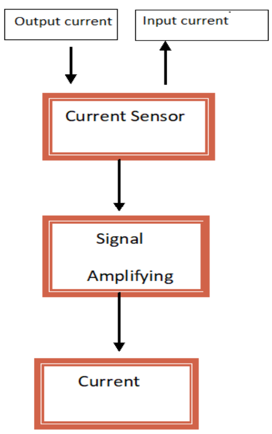

Fig.6. Schematic of current sampling module

4 Battery Hardware in Loop System

The battery HIL system can provide the signals into the BMS just as the signals from a real battery in vehicle. The Signal Generator output all signals including voltage of cells, temperatures, current, commands from Vehicle control unit(VCU), etc. The output signals be delivered not only to the BMS but also to the signal processer at the same time.fig.7. The evaluating block compares the two signals to calculate the error of the BMS. Then output the results about the BMS.

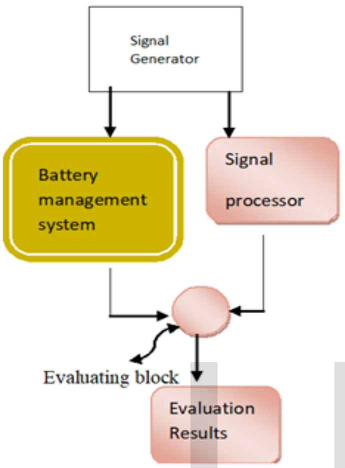

Fig.7. Block diagram of HIL

4.1 The main functions of the HIL are:

1. Evaluating the BMS performance, such as accuracy, linearity, signal collecting unit;.
2. Evaluating the accuracy of BMS algorithm of estimating SOC, SOH, etc.
3. Battery diagnostics method tests.
4. BMS algorithm parameters calibration.
5. Standardizes validation of major releases and incremental algorithm changes.
6. Lowcost:- does –not require expensive pack cyclers or environmental chambers.
7. Identifies areas of sensitivity to direct focused efforts in future development.

4.2 BMS verification with Hardware in loop system

A general test process of BMS with HIL system includes the following steps. As shown

1. Analyzing battery electrochemical to modeling, at the same time Battery charge and discharge experiments be done for parameters.
2. Refine the battery model.
3. Generate Battery signals, that including battery cell voltage, battery temperature, battery current, and command from Hardware control unit(HCU).
4. Output of the battery signals to both BMS and signal processor.
5. Data logging analysis output the performance of the BMS.

5 Lithium Ion Battery

5.1 Desirable to use Li- ion battery

1. Good heat conduction:

The cell shows better heat conduction than cylindrical cells, because it has wide planes on both sides.

2. Efficient packing configuration:

The cell packing efficiency allows for a smaller assembled battery as compared with cylindrical cells. Experienced assembly methods like those used for prismatic Ni-Cd batteries can be applied for our Li-ion battery because of the similar shape .

3. High productivity:

The cell has high productivity because its elements are easily manufactured by winding the electrodes and the separators. The productivity is higher than that of stacked electrode type cells.

4. Low internal short-circuit possibility :

The cell has never caused internal short-circuit except under test conditions such as nail penetration abuse testing. The cell uses a one-piece positive and a one- piece negative electrodes, this gives much fewer "electrode edge portion" than stacked electrode type cells.

5.2 Lithium ion batteries formation

Li-ion batteries can be constructed and packed in two major formations, which are metal cans either in cylindrical or prismatic shapes or laminate films (stacked cells) that are familiarized as Li-ion polymer batteries. Li-ion batteries can be shaped as the cylindrical structure of rolled and plastered layers in metal cans with electrolytes. In the stacked form, the three layers are confined in laminate film and where their edges are heat-sealed aluminized plastic. A gel or polymer is often used to prevent the electrolyte from leaking in this package. For the energy source in EVs, Li-ion cells must be assembled into modules and then further composed into battery packs of series- parallel connected cells to achieve the precise energy demands

5.3 Lithium ion battery management system

Li-ion battery powered EVs are becoming very effective and applicable as clean transportation alternatives through out the world. The EV systems can have a positive impact in the global economy and environment. To enhance its performance for service length, EV systems need to be safely maintained, including the safe operation of the ESS in the vehicle that is vital to EV technologies. The battery management system(BMS)manages all the control and management facilities regarding the energy storage and transfer in EV systems such as charging and discharging control, battery cell voltage monitoring and balancing, battery charge equalization, input/output current and voltage monitoring, temperature control, battery protection, fault diagnosis and assessment. The BMS controls the charging of battery as per the battery properties and the charge state of the battery. It controls the battery discharging on the basis of the load demand and the charge available in the battery systems. The battery cell voltage levels need to be measured by the BMS to estimate the charge states of the battery cells and to protect the cells from overcharging and undercharging. The battery cell balancing through charge equalization techniques should be implemented by the BMS to enhance the overall performance and life of batteries. The BMS controls the operating temperature at certain levels to perform the energy conversions and manages the heat for safe operation. The protections from voltage/current stress, overvoltage, short-circuit, overcurrent, hysteresis, etc., are affirmed by incorporating sensors, relays and breakers in the BMS of EV systems. The BMS diagnoses and assesses the faults that usually take place in EV systems concerning the entire processes of energy storage and power delivery.

5.4 Battery cell monitoring system

The EVs use a series Li-ion battery cells in a pack. The battery cell may behave differently during the run-time. Therefore, continuous battery cell monitoring is needed for investigating the cells' conditions. The battery cell monitoring results might aid the system performances by managing, protecting, equalizing and controlling operations. It indicates the necessity of the charge and discharge control, the protections from the overcharged and undercharged cell conditions, the control of the temperature and heat, the communication and interface for data acquisition, and the fault diagnosis and assessment, etc.

6 Challenges in BMS

A literature review has revealed that BMSs are still in a premature stage. Even if state-of-the-art algorithms and monitoring methods were developed and applied in EVs, the reliability of BMSs would still make end users suspicious. Thus, the gap between the laboratory tests and the real requirements should be addressed by future research. Generally, the estimation and prediction methods have unfeasible hardware requirements, such as, impedance measurement, which is costly and not practical in many BMS applications today. Meanwhile, the high computational complexity depends on costly hardware, such as, the central processor. It can be seen that the trade off between high performance and feasibility in a BMS is important. Furthermore, most studies are performed in a laboratory environment and are conducted using full charge-discharge cycles. The performance of BMSs under operating conditions, such as vibration from bumpy roads and temperature extremes from snow, rain or summer heat, has rarely been studied. These external loads will be reflected in the battery's available capacity. Thus, it will add un-modeled effects not taken into account in existing algorithms and models. As persent scenario The charging time required is about 6 to 8 hours when normal charging is considered, which imposes another challenge of time management. While talking about fast charging this can go well under 90 minutes or less, but this depends on the availability of charging stations. DC charging points need charging infrastructure, which is yet another difficult to overcome.But some of leading EV companies across globe like Tesla,Nissan,Mahindra has taken initiative and also laid charging satations,Moreover with the growth of battery applications, disposal and recycling problems also arise.

6.1 Possible Solutions for BMS

Prognostics and health management (PHM) is an enabling strategy consisting of technologies and methodologies for BMSs. By monitoring the sensor signals and processing real-time data from a BMS, the battery status, including SOC and SOH, can be estimated and predicted to provide end users with an accurate "gauge meter" in an EV. Based on the data collected, the BMS determines the corresponding maintenance strategies. Meanwhile, abnormality detection can be used to capture signals to update the predictive results and guarantee the safety and reliability of batteries. In terms of inaccessible internal reactions of the battery and varying external loads, accurate battery modeling should be established that takes into account imposed factors. Regression technology combined with the state-space models are proposed as a competitive approach for battery degradation modeling. The regression approaches use data training to fit degradation trend curves based on specific battery materials. Our view is to measure and collect current, voltage, and temperature as the main operational parameters in order to improve feasibility and reduce design costs.

7 Battery Protection

Li-ion batteries are applied for energy storage systems in EVs with a number of series-connected battery cells in a pack.(seen in fig.3) EV batteries may be charged from the external source and discharged to run the EV driving motor and systems.The consecutive charge-discharge cycle may cause a voltage and charge imbalance among the battery cells because of changes in their physical characteristics.This imbalance happens due to manufacturing, temperature, and cell ageing problems. Imbalanced voltage and charge profiles may reduce the overall performance and durability of energy storage systems Overcharging might cause cell explosion, whereas undercharging might damage the chemical properties of the battery and shorten the life of the battery cells. The BMS may terminate the charging and discharging of the battery when it is out of the operation range. Thus, the battery pack may lose the rated charge level needed for the operation. Therefore, the charge equalization controller for the series connected battery pack is essential to protect the battery cells and to maintain the storage capacity and operation rating.

7.1 Advantages of BMS

1. Maintains battery in a state in which it can fulfill its functional design requirements.
2. Protects the safety of the battery operated device's and Detects unsafe operating conditions and responds.
3. Protects cells of battery from damage in abuse/failure cases.
4. Prolongs life of battery (normal operating cases).
5. BMS is to keep track of the state of charge (SOC) of the battery.
6. Simple in Coulomb counting.
7. Simple and easy to predict capacity fade and internal resistance increment.

7.2 Disadvantages of BMS

1. Complex in AC impendence.
2. More computationally expensive than non feedback methods and highly depend on model accuracy.
3. Sensitive to the amount and quality of training data.
4. Open loop sensitive to the voltage sensor precision, unsuitable for cell with flat curves.

8. Future Scope

1. The BMS optimization algorithm could be further improved by considering the cost of each charge of each cells as an technoeconomical and discharge cycle of battery to prevent excessive activities that could shorten the battery life.
2. Algorithms can be developed to predict power usage and generation in the microgrid, Such algorithms can be integrated with optimization-based power flow control method for real time energy management in the microgrid.
3. New transmission capacity and better operating practices, such as greater automation controller, forecasting, renewable energy visibility, and transmission planning methods, market integration and implementation of smart energy management systems can resolve the problems and challenges for grid operators, often circumventing the need for curtailment.

9 Conclusion

1) Advanced BMS can significantly improve the performance of EVs.

2) Adaptive mathematical models are an efficient tool for improving and refining BMS.

3) The State-of-Charge determination algorithms, developed with the help of adaptive battery models, are highly precise and represent a good basis for practical implementation.

4) BMS is a critical component of electric vehicles. That promotes guarantee safe, efficient and reliable battery operation.

5) The combination of advanced charging algorithms and adaptive S BMS improves the battery functioning thus improving the characteristics of EV.

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