International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 3, Issue 4 (July-August 2015), PP. 08-12

AN INSIDE LOOK IN THE ELECTRICAL STRUCTURE OF THE BATTERY MANAGEMENT SYSTEM TOPIC NUMBER: RENEWABLE POWER SOURCES, POWER SYSTEMS AND ENERGY CONVERSION

Cristina Pitorac.
Electrical Engineering. Country: Germany.
cpitorac@gmail.com

***Abstract*- The batteries used in electric and hybrid vehicles consists of several cells with voltages between 3.6V battery and 4.2 V in series or parallel combinations of configurations for obtaining the necessary available voltages in the operation of a hybrid electric vehicle. How malfunction of a single cell affects the behavior of the entire battery pack, BMS main function is to protect individual cells against over-discharge, overload or overheating. This is done by correct balancing of the cells. In addition BMS estimates the battery charge status.**

I. INTRODUCTION

The battery management system is the key component of every alternative propulsion system that haves in the structure a battery pack.

A. Battery management system construction

It is divided into two parts, namely BMS Master and cell mode controller, connected via CAN. Each unit cell is controlled by a controller CM. CM is responsible for measuring cell voltages and start-up the discharge of individual cells. To do this, to every cell is assigned a transistor. When the transistor is turned on, the load cell is connected through a resistance. Balancing operation occurs by shunting the cell with the highest tension.

Each BMS is designed so that it can control between 9 and 15 groups of 4-12 cells.

To check the battery, BMS must measure and examine the current, temperature and voltage of each cell separately. From these basic measurements can be calculated the secondary data that may provide more information about battery status. This information also affects battery control system.

Based on basic measurements, BMS protects the battery against exceeding the limit voltage and temperature limits, and sets the maximum current allowed for unloading or loading and estimates SOC, DOD the internal resistance of the cell, thus providing information on battery status. To maximize battery performance, BMS also controls the passive cell balancing.

To be able to report to the user and to communicate with the other devices BMS is in vehicle electric connected to the CAN.

BMS is designed modular to facilitate diagnosis and partial replacement of defective items. The system is divided into small modules that can be independently created, improved and used in different systems to create a multiplier functionality. The modules are independent of each other, which means that replacing or removing a module does not affect the functionality of other modules.

B. Methods of measuring of the current and cell voltage

There are two ways to measure current in an electric vehicle. A measurement method is represented by a Hall Effect sensor wire around the cable through which current flows. Hall Effect is based on measuring the magnetic field around the cable, which is proportional to the electric current passing through the cable. Another method is represented by the use of a shunt resistor. This type of resistor usually has very little resistance to the current flow generates a voltage proportional to its size.

Current is measured primarily through two effects:

- Resistance drop: passing electric current through a substance, a potential difference appears that for most materials is proportional to the current (Ohm's law). By measuring this voltage can determine the current.
- Magnetic field generated -: movement of electrical charges creates a magnetic field oriented perpendicular to the direction of movement. Electric current can be determined by measuring the magnetic field. The major advantage of this method is galvanic isolation, meaning there is no direct electrical contact between the measuring circuit and measuring circuit.

In the case of the notification of resistive current sensing resistor is placed in series with the circuit whose current should be measured and measure the voltage drop across the resistor. Current is determined from Ohm's law: $I = U / R$

The disadvantages of this procedure are:

Voltage drop across the resistor sensing influences the operation of the circuit in which is inserted.

Current passing through the resistor will generate voltage drop and heat addition per time unit $P = I ^ 2 R$

Electrical resistance slightly depending on temperature, ambient temperature change and additional heating due to the passage of electric current will result in a deviation from Ohm's law, linear voltage dependence of current. Because the temperature changes are not instantaneous, resulting nonlinearity is difficult electronically compensated. Is needed a good heat dissipation system to limit the temperature of the resistor trip.

The current can be noticed through the magnetic field that it generates. The main advantage of the method consists in the absence of direct electrical connection between the measuring circuit and measuring circuit.

A good magnetic sensor for current is the sensor with Hall Effect. It measures the magnetic field around the wire passing current, whose size is proportional to the electric current. The Hall voltage is analyzed within the sensor and converted to the corresponding value, depending on the measurement electronics inside the sensor. The resulting size is sent via CAN and thus read by BMS.

BMS requires a sensor to measure voltage to check the status of contacts, to control the pre-charge and to measure the voltage of the battery. The read value will be read via CAN by BMS.

C. BMS Master

BMS Master is the heart of the battery management system and is responsible for all system control functions. Master is connected to all other components through CAN that allows a quick communication and so it receives all the necessary data to perform control operations. This device is a real-time operating system that calculates information all the time and who takes care of the proper functioning of the whole.

The BMS Master is fully programmable. It has two pins for CAN connection and a number of I/O analog and digital pins. BMS Master consist of two main controllers (MC). One is responsible for active mode and the other to sleep mode. Besides the two controllers there are up to 30 battery monitoring systems (BMON) isolated from the battery and the battery pack connected to the modules. Each BMON can monitor up to 5 12V batteries in accumulator package, up to 4 auxiliary sensors for temperature and 4 pressure sensors. BMON are interconnected so that allows the CAN bus communication. A typical construction for BMS consists of 2 MC and 7-8 BMON.

MC consists of a dual core processor in order to perform all necessary functions: communication, processing and control, saving and data recovery.

History of the battery pack is stored throughout the life of the battery in RAM. Complete information about the last 30 cycles are stored at an interval of 2 weeks or depending on the level of use of the battery.

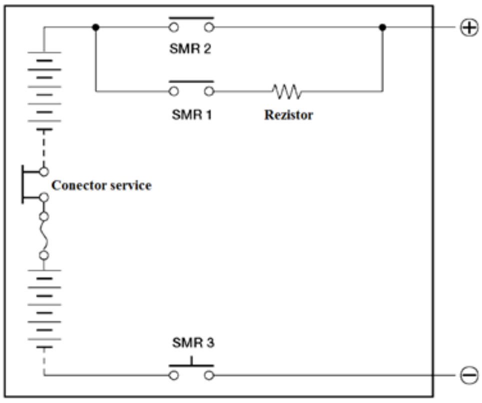
MC is equipped with a communication interface with the charger or vehicle charger. This site allows BMS to control DC fast charge and slow charging from AC power. Additionally the interface is attached to a data port for maintenance and system diagnosis.

The main function of BMS system is the safety operation. Since BMS has full control of the charging and discharging safety function such as starting lock, load line control, and check polarity charger. Power losses are also part of the battery management system tasks.

Battery control unit has the following functions:

- Current estimation for charging/discharging process
- estimate the amount of heat generated during charging and discharging of the battery
- monitoring of temperature and battery voltage

The main relay (SMR) connects and disconnects high voltage circuit power source under the order of the BMS. When the circuit is switched on the SMR 1 and 3 are starting. The resistor connected in series with SMR 1 protects the circuit of the initial excessive current. Then it started SMR 2 and SMR 1 is stopped and allowing the current to flow in the circuit.



In the moment of disconnecting the system, SMR 2 and SMR 3 are switched off in this order and BMS checks if there relays where closed.

D. Battery module controller

BMS is divided in two parts, BMS Master and Battery module controller, connected via CAN. Each battery module is controlled from a controller CM. CM is responsible for cell voltage measuring and for discharge initiating of each cell.

The battery pack contains up to 15 modules controlling battery voltage and temperature of each cell in part, information that is sent to BMS Master. Each controller has an identification number in order to facilitate the diagnosis of system.

0	00340000	X	0									13.660120	R
0	13D40F00	X	8	09	2B	09	2D	09	2D	09	2D	13.685600	R
0	13D40100	X	8	09	2C	09	2D	09	2D	09	2E	13.686140	R
0	13D40200	X	8	09	2D	09	2C	09	2D	09	2C	13.686690	R
0	13D40300	X	8	09	2C	09	29	09	2C	09	2D	13.687240	R
0	13D40400	X	8	09	2E	09	2E	09	2D	09	2E	13.687790	R
0	13D40500	X	8	09	2D	09	2F	09	2F	09	2D	13.688330	R
0	13D40600	X	8	09	2C	09	2F	09	30	09	30	13.688880	R
0	13D40700	X	8	09	34	09	37	09	38	09	37	13.689430	R
0	13D40800	X	8	09	2A	09	2B	09	2C	09	2B	13.689980	R
0	13D40900	X	8	09	30	09	2F	09	2E	09	2E	13.690530	R
0	13D40A00	X	8	09	2C	09	2D	09	2F	09	2D	13.691080	R
0	13D40B00	X	8	09	2C	09	2C	09	2F	09	2B	13.691620	R
0	13D40C00	X	8	09	2F	09	30	09	2F	09	2A	13.692170	R
0	13D40D00	X	8	09	2C	09	2C	09	2E	09	2D	13.692720	R
0	13D40E00	X	8	09	2B	09	2D	09	2E	09	2B	13.693270	R
0	13D41000	X	8	09	32	09	2F	09	31	09	32	13.693820	R
0	13D41100	X	8	09	2C	09	2B	09	2D	09	2D	13.694360	R
0	13D41200	X	8	09	26	09	2A	09	29	09	29	13.694910	R
0	13D41300	X	8	09	33	09	34	09	32	09	33	13.695460	R
0	13D41400	X	8	09	2C	09	2C	09	2B	09	2C	13.696020	R
0	13D41500	X	8	09	2C	09	2C	09	2C	09	2D	13.696570	R
0	13D41600	X	8	09	2F	09	2F	09	2B	09	2C	13.697110	R
0	13D41700	X	8	09	2C	09	2A	09	2A	09	2A	13.697660	R
0	13D41800	X	8	09	33	09	32	09	34	09	32	13.698210	R

Module controllers contain 1kV galvanic isolation between each cell and the rest of the vehicle. The voltage can be measured on a range of values between 0V and 5V and the temperature between -40 and 100 ° C. The supply voltage is 6.6 V and is produced by the low voltage supply system. The controllers do not perform any processing of information and does not perform measurements without master's command.

BMS measuring Master send command to the CAN controllers every second. All controllers identify and measure the voltage and temperature control cells. After measuring controllers send information to the BMS Master via CAN. Thus every second master has new information about the voltage and cell temperature.

E. High voltage switch

The switch is independent and controlled by CAN of BMS. BMS Master controls all switches and high voltage relays in the system.

Every time one of the switches is opened or closed, the information is sent via CAN to the BMS Master, helping to increase the safety in operation of the entire system, comparing the command sent to the switch an the state of the switch.

F. BMS Memory

When stopping the vehicle, BMS write the last parameters resulting from the battery. Stopping the vehicle is done so a few seconds after receiving the order. When starting the vehicle, BMS read the last data written to memory and begins to update. During charging or discharging BMS battery saves data every 30 seconds. This function allows access to new information about battery status and its history.

G. Voltage and current sensor IVT-MOD

Electric vehicles need a method to measure current in real time thus limiting the maximum current permissible by charging or discharging.

The name of the sensor comes from th fact that ist programmable and modified from the user and used in and used in different applications.

The sensor characteristics are:

- Galvanic isolation
- Overcurrent detection
- Activation signal hardware
- 6 Classes current measurement
- Up to 3 channels to voltage measurement
- Digital communication (CAN, SPI (Serial Peripheral Interface))
- Temperature measurement

The sensor automatically sends the measured values via CAN to the BMS Master. BMS Master read the values and calculates the maximum permissible limits of dynamic power in battery operation and monitors the battery voltage.

H. Pre-charge resistor

Using a precharge resistor is essential if a charging source is connected to the electric vehicle. Preload resistance is connected in series with the battery and charging the battery power during the session of preload.

When the battery is connected to the power supply will be a short current pulse to charge capacitors in the battery. Precharge resistance limits the current pulse. Preload session is completed, usually in less than a second. After the precharge operation battery can be connected directly to the power supply, avoiding the precharge circuit resistance. The precharge resistor serves to protect the circuit, avoiding the risk of damage to components in series with it.

I. High voltage contactor

High voltage contactor and precharge resistor are responsible for connecting and disconnecting the vehicle battery from high voltage charging source.

Precharge relay, which is connected in series with the precharge resistor is used during the session of preload to limit the current pulse, thereby preventing the risk of damage intermediate circuits.

II. BMS SYSTEM CONFIGURATION

BMS is functioning after a logical scheme.

Based on this scheme is seen as BMS has the following operating states:

- An error
- Start mode
- Stop mode
- Preload condition (Drive Mode)
- Preload condition (Load Mode)
- Driving Mode
- Charge Mode

In parallel, BMS performs the measurement operations, updates and saves data after the initial verification.

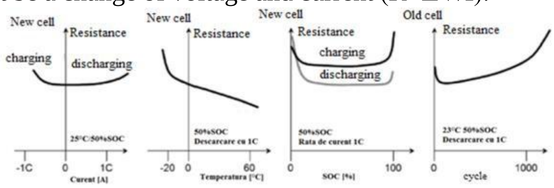
When BMS Master is started, Start mode will be automatically activated. In this way will make first contacts and cell checks before proceeding to the next step. If the check initial has favorable results, BMS check what mode has been activated, driving or charging. From this information depends on how BMS's subsequent action, i.e. whether to begin operation Driving mode or Charging. BMS will not be able to return to a previous state. The only possibility is to continue to the next step, according to the information and operating parameters of the system.

In the event of an error, BMS Master enters the error state and performs directly to the shutdown mode, when it saved all the important data.

III. BMS CONTROL ALGORITHM BASES

A. The internal resistance

In real life, internal resistance is a dynamic factor and depends on many factors. To calculate the internal resistance must be a change of voltage and current (R=ΔV/I).



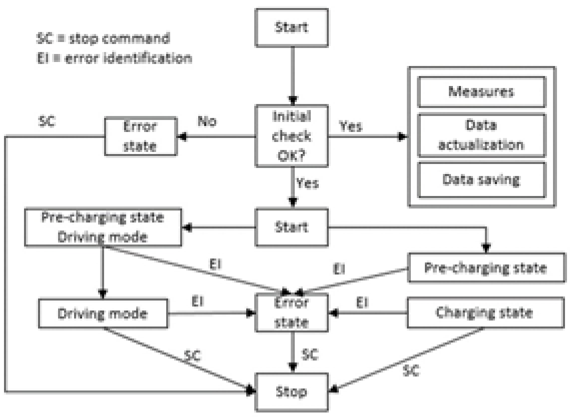
Dynamic internal resistance varies at least of the state of battery charge, current, temperature and number of cycles of life. Current direction also has an effect on this parameter.

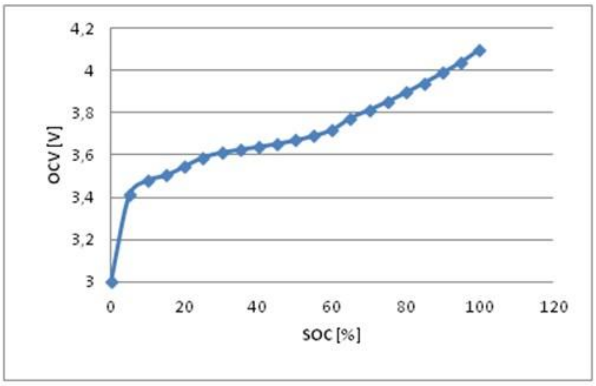
B. SOC Estimation

BMS needs a battery model that is self-adjusting. The algorithm for determining the available capacity and the "mileage available" include the calculation of the battery capacity according to the nominal capacity of the battery. A correction factor is calculated according to temperature and is introduced in the calculation of the state of charge SOC.

SOC calculation takes into account the losses due to internal resistance and battery voltage.

The problem of determining the state of charge is that it cannot be directly measured. Therefore this parameter will always be estimated, estimation hampered of the variability of the cell functioning depending on the condition.

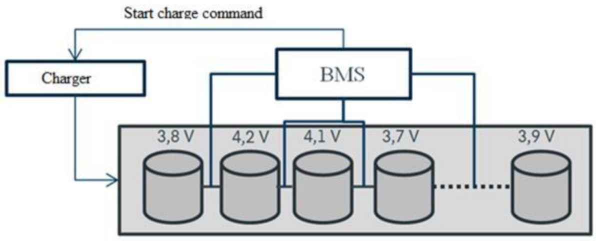




During operation, the cells will always be unbalanced, with various SOC, hence there will be two different cells that will help determine the battery SOC, namely that strike the maximum allowable voltage at charging, in which case it will be 100% SOC and the first that reaches the minimum allowable voltage and the SOC will be 0%. The Ah obtained if the battery is discharging from 100% to 0% is the battery capacity. An unbalanced battery capacity will be always smaller than the capacity of a balanced battery.

C. Battery balancing

The cell balancing is not determined by their internal resistance electrical losses but individual cells electrical loses. Balancing phenomenon of the lithium cells need not be performed often very due the very small currents of self- discharge.

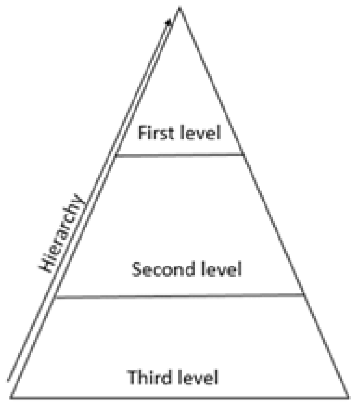


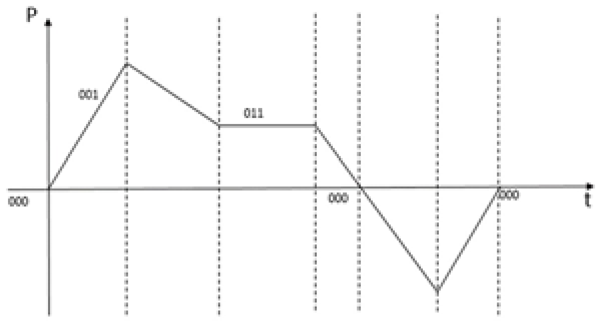
If the series connections, the first cell that reaches the minimum voltage cutting discharge determine battery capacity. Although other cells can still be discharged, the operation will be halted because the current will pass through the weakest cell and discharging it over the allowed limit, thus bringing the battery outside the range of its safe operation (SOA - Safe Operating Area). The same thing will happen when charging the battery.

During charging, by switching on the transistor, the current is dissipated along the cell with the highest tension, and thus will be charged at current rates lower, i.e. slower than other cells. During discharge, turning on the transistor increases the effective load of the cell and thus the cell will discharge at higher current rate, i.e. faster than other cells.

IV. MODULAR BMS CONSTRUCTION

The BMS software construction can be looked as a modular construction which consist of three command levels.





Based on these description above and on the state of system operation can be described the function map.

Starting from a driving cycle it can be identified the states of the system and the resulted information could be grouped in modules assigned to the three level system functionality of a battery management system.

V. ACKNOWLEDGMENT

The battery management system is the heart of a high voltage battery system which controls the two more importants function in a battery system, power request and safety in operation.

Each of these level has his decision frame and between them flows the process dissemination. The first level has the biggest decision frame and it controls the second levels. The second level has the second biggest decision frame after the first level and controls the third level. The third level has the smallest decision frame and responds to the second level.

As application for the BMS the first level could be responsible for the energy management, the second level for the power management and the third level for the power electronics.

The first level is slow dynamic because the supervised parameter are slow changing. It looks always at the SOC, vehicle operating mode, which need a periodical manipulation of a control data. It decide the system operation strategy.

The second level controls the power split strategy of the system between the multiple energy sources for a satisfying answer to the load request. It needs faster dynamical response as the first level and has biggest influence on the system technical as the first level. For example it can prevent the over charge/discharge, control the power fluctuation etc.

The third level could 'speaks' directly with the cell and is responsible for the voltage and current regulations.

REFERENCES

[1]. Dipl.-Ing. Markus Plöger, Dr.-Ing. Hagen Haupt, Dipl.- Ing. Jörg Bracker, dSPACE GmbH, Germany 'HIL Testing of Battery Management Systems' Automobil Elektronik 10/2011
[2]. DHAMEJA, S. 'Electric Vehicle Battery Systems', 2001
[3]. USABC,'Electric vehicle battery test procedures manual',1996
[4]. Carlos Martinez, 'Cell balancing maximizes the capacity of a multi cell LiIon battery packs', 2002
[5]. Freedom Car, 'FreedomCAR Battery Test Manual', 2003
[6]. US Department of energy, 'Battery Test Manual for Plug-In Hybrid Electric Vehicles', 2008
[7]. Journal of Power Electronics, Vol. 10, No. 2, March 2010,' Design Considerations of a Lithium Ion Battery Management System (BMS) for the STSAT-3 Satellite',2010
[8]. H.J. Bergveld, 'Battery Management Systems Design by Modelling',2001
[9]. Leon C Rosario, 'Power and Energy Management of Multiple Energy Storage Systems in Electric Vehicles', 2007