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Reliable battery operation — a challenge for the battery management system

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Abstract

Advanced batteries, like lithium-ion batteries, are more sensitive in case of irregular operation than conventional batteries. Therefore, the operation of such batteries must be controlled by a management system. The features of a battery management system depend on the application, but in most cases, features like battery state determination, electrical management and safety management are necessary. This paper describes these functions of a battery management system. The use of a battery management system will lead to an increased lifetime and a safer operation of the battery. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Battery; Battery management system; Lithium

1. Introduction

The increasing usage of batteries in different applications, in particular, advanced battery systems like lithium batteries and high temperature batteries, makes it necessary to control the battery terms of, e.g., power flow, temperature control, safety control and so on. Therefore, a battery management system (BMS) is required, taking the special demands of the battery technology into account. As input signals voltages, currents and temperatures are measured. The function of a BMS can be split into the following tasks:

- Data acquisition
- Battery state determination
- Electrical management
- Thermal management (not always necessary)
- Safety management
- Communication.

Fig. 1 shows a simplified schematic drawing of a BMS.

In case of small batteries, some of the above-mentioned functions are available as single or multiple chip solutions [1]. For example, Li-ion battery packs for cellular phones and laptop computers contain as a minimum a safety management system. In the case of larger battery systems, as for example, EV batteries, the BMS is more complex and BMS must be individually developed for the battery technology and the application [2].

2. Data acquisition

All algorithms of the BMS use measured and calculated data as input information. Therefore, the accuracy, the sampling rate and the characterisation of front end filtering are very important and depend on the type of application. For example, the sampling rates of EV applications are faster than 1 sample per second whereas in the case of photovoltaic applications sampling rates below 0.2 samples per second are used.

3. Battery state calculation

The battery state is used inside the battery management as an input parameter for the electrical management and additionally, it is an important parameter for the user. So the battery state can be used to estimate the range of an electric vehicle or the expected lifetime of the battery.

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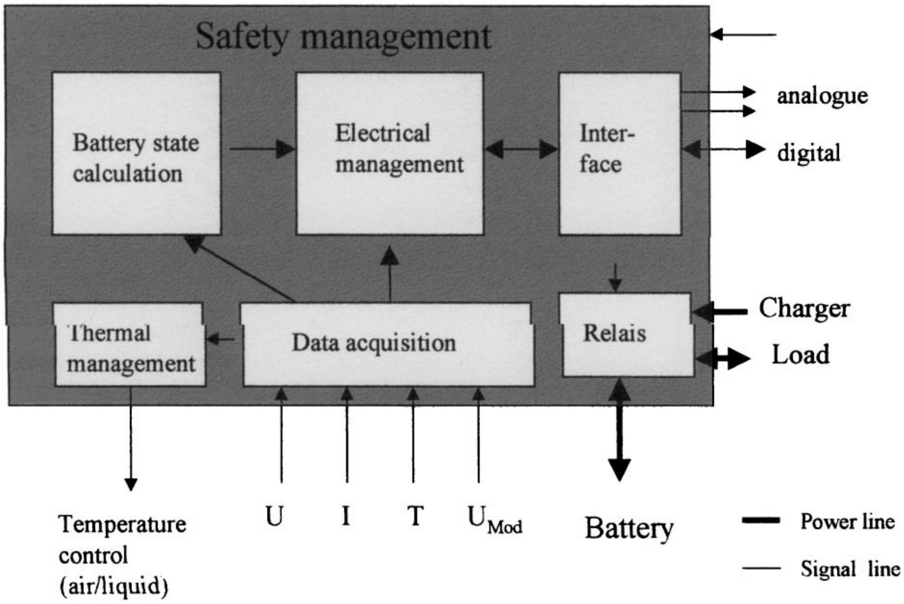

Fig. 1. Schematic structure of a BMS.

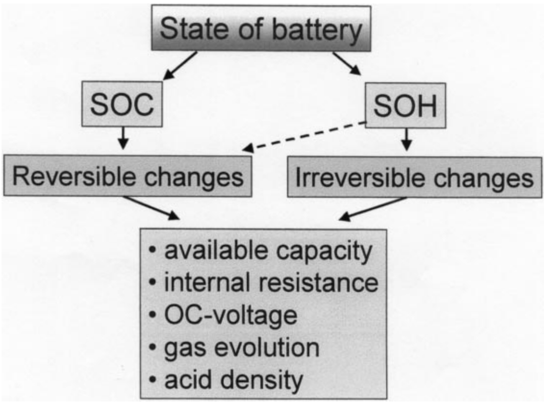

Fig. 2. How to understand the state of the battery?

The state of the battery can be simply described by the following two parameters:

- State of charge (SOC)
- State of health (SOH).

Both parameters influence internal battery parameters as is shown in Fig. 2.

For SOC determination, in most cases Ah counting, including charge loss estimation are used [3]. For SOH determination, a couple of more or less good working methods are known and used and it depends strongly on the battery technology and the kind of application which method is useable.

Fig. 3 shows a method using an optimum filter algorithm for SOC and SOH determination. Other methods like

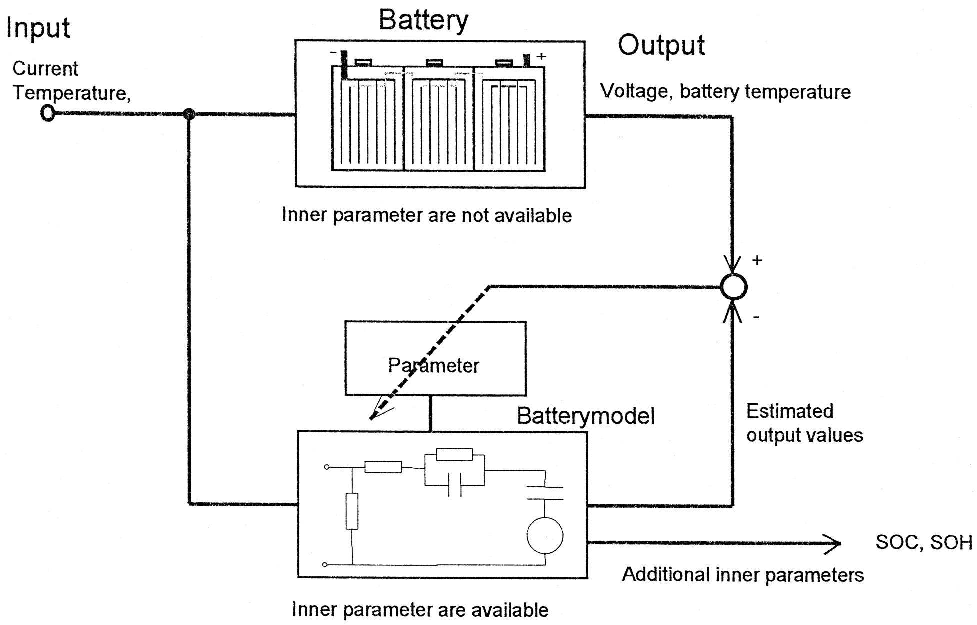

Fig. 3. Adaptive method for battery state determination.

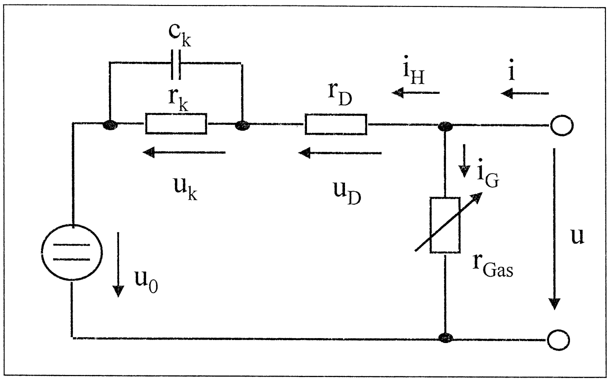

Fig. 4. Battery model for battery state determination.

fuzzy clustering and neural networks have also been developed and tested [3].

As optimum filter, a Kalman Filter is used. The basic of such a filter is a battery model that is shown in Fig. 4. The Kalman Filter takes the statistical knowledge of the parameter and the measurement into account. The deterministic knowledge, described by the differential equations given by the battery model shown in Fig. 4, is corrected by the statistical knowledge. The main advantage of this method in comparison to Ah-counting is that the SOC calculation is not influenced during long-term operation (problem of drift).

4. Electrical management

Within the electrical management the input parameters current, voltages, temperatures, SOC and SOH are used to control the charge and discharge process. The following tasks must be fulfilled:

- Control of the charge process, including equalization charge
- Limitation of the discharge current by SOC, SOH and temperature.

The charge control process and the discharge limitation depend strongly on the battery technology used and the battery type (Fig. 5).

5. Safety management

The safety management has to protect the battery against critical operation conditions. In case of a BMS for an electric vehicle, the tasks of the safety management system are:

- Protection against deep discharge
- Protection of single cells against overdischarge
- Protection against over-temperature
- Battery turn off in case of a crash.

Overcurrent and overvoltage should also be detected by the safety management.

6. Thermal management

A thermal management is necessary for most high power applications and for high temperature batteries. The tasks of the thermal management system are temperature equalization between the cells, cooling of the battery and in some cases, i.e., high temperature batteries, the heating of the battery. Therefore, liquid or air (fan) systems are

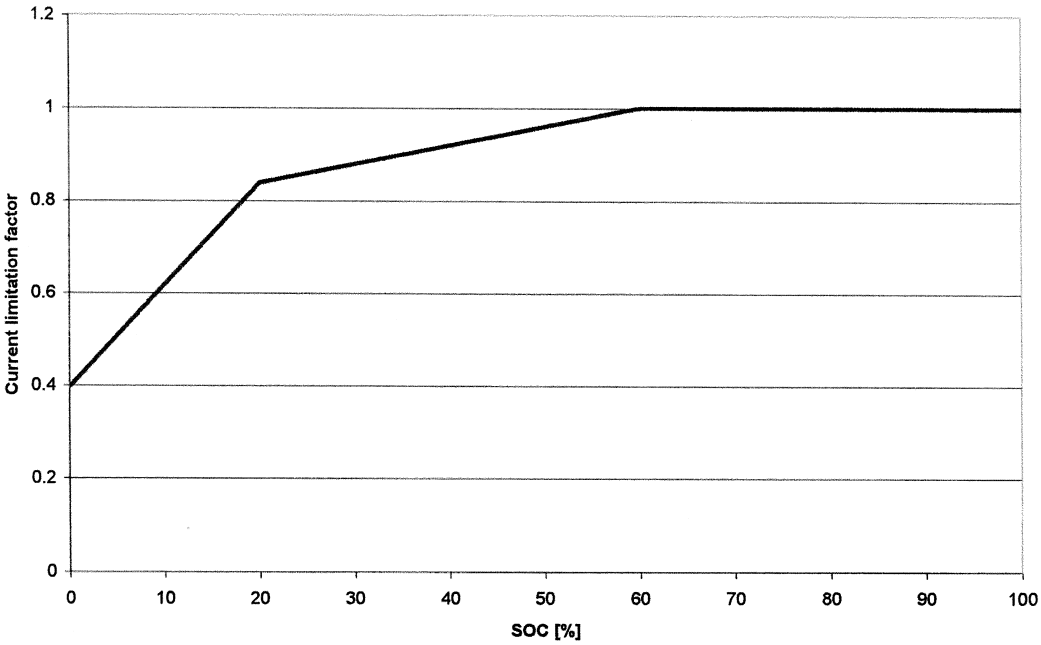

Fig. 5. Function for current limitation vs. SOC.

used. One major problem is the heat transfer from the inside of the battery cells to the outside, because the thermal resistance of the electrolyte and the plastic cell housing is quite high.

7. Communication

The communication between the BMS and other on-board and off-board devices is another important task of the BMS. Depending on the application, different interface systems for data exchange are used:

- Analogue signals
- Pulse width modulated signals
- Serial interface like CAN-Bus or I^2C or others.

8. Conclusions

This presentation shows that several features must be fulfilled by a BMS. These features must be optimized for the battery technology and the kind of application.

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