Novel Battery Thermal Management System for Greater Lifetime Ratifying Current Quality and Safety Standard

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Novel Battery Thermal Management System for Greater Lifetime Ratifying Current Quality and Safety Standard

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Temperature excursions and non-uniformity of the temperature inside the battery systems are the main concern and drawback for any attempt to scale-up battery cells to the larger sizes as required for high power applications. The applications may include electric generating stations, substations, vehicles, telecommunications installations, large industrial and commercial installations, large uninterruptible power supply (UPS) installations and renewable energy plant installations etc. The capacity of the battery pack increases as the operating temperature is raised for a battery pack however this come with the very high expense of accelerated capacity fade i.e. ageing. Subsequently the lifetime of the battery system is reduced. Moreover poor performance (limited capacity availability) is observed at low operating temperature [1,2]. In addition, excessive or uneven temperature rise in a system or pack reduces its cycle life significantly [3].

In general, temperature affects several aspects of a battery including:

- operation of the electrochemical system;
- round trip charge/discharge energy efficiency;
- charge acceptance;
- power and energy capability;
- reliability;
- lifetime and life cycle cost.

Thereof, temperature uniformity, within a cell and from cell to cell inside a pack (a collection of cells) and/or system (a collection of packs), is important to achieve maximum cycle life of cell [4]. The battery thermal management system (BTMS) is an important and integral part of battery management system (BMS) for this exact purpose. Basically, battery system design requires a trade-off between the risk of overheating individual cells of relatively large sizes and the cost of insulating or cooling a complex array of small cells. Usually BTMS is comprised of combination of both hardware and software to preserve the temperature difference of battery cells in a pack in an optimal range to enhance the lifetime while ensuring safe and secure operation. Simulation results showed that thermal management systems might improve battery performance by 30–40% [5]. However, employed cooling systems may introduce higher level of complexity in the design and operation of the battery system. Depending on the electrochemical- physical characteristics couple and the corresponding reactions the optimum operating range of different battery is dissimilar. In general, the optimum range for different batteries requires to be operating near room temperature (15º-35ºC). Inside a battery pack depending on the location of each stack or system, external ambient conditions, the employed heating and cooling method could create an uneven temperature distribution in the pack. This uneven temperature in the cells could trigger an uneven temperature distribution in the pack. As a result, the pack could lead to unbalanced system that will restrict the optimum performance as well as triggering local degradation, consequently reducing the lifetime in longer run of the operation of the battery pack that is designed for. Depending on the electrochemistry and working temperature each kind of the cells works better on different circumstances and working temperatures. So in order to achieve these goals and circumvent the problems discussed above BTMS may play a vital role to lengthen the battery pack lifetime as well as to ensure the optimum performance level. The other important impact of a battery packs operating temperature is the electric balance among the cells or systems in the whole battery pack ecosystem. Fig. 1 corresponds a generic battery thermal management system operating on a desired application.

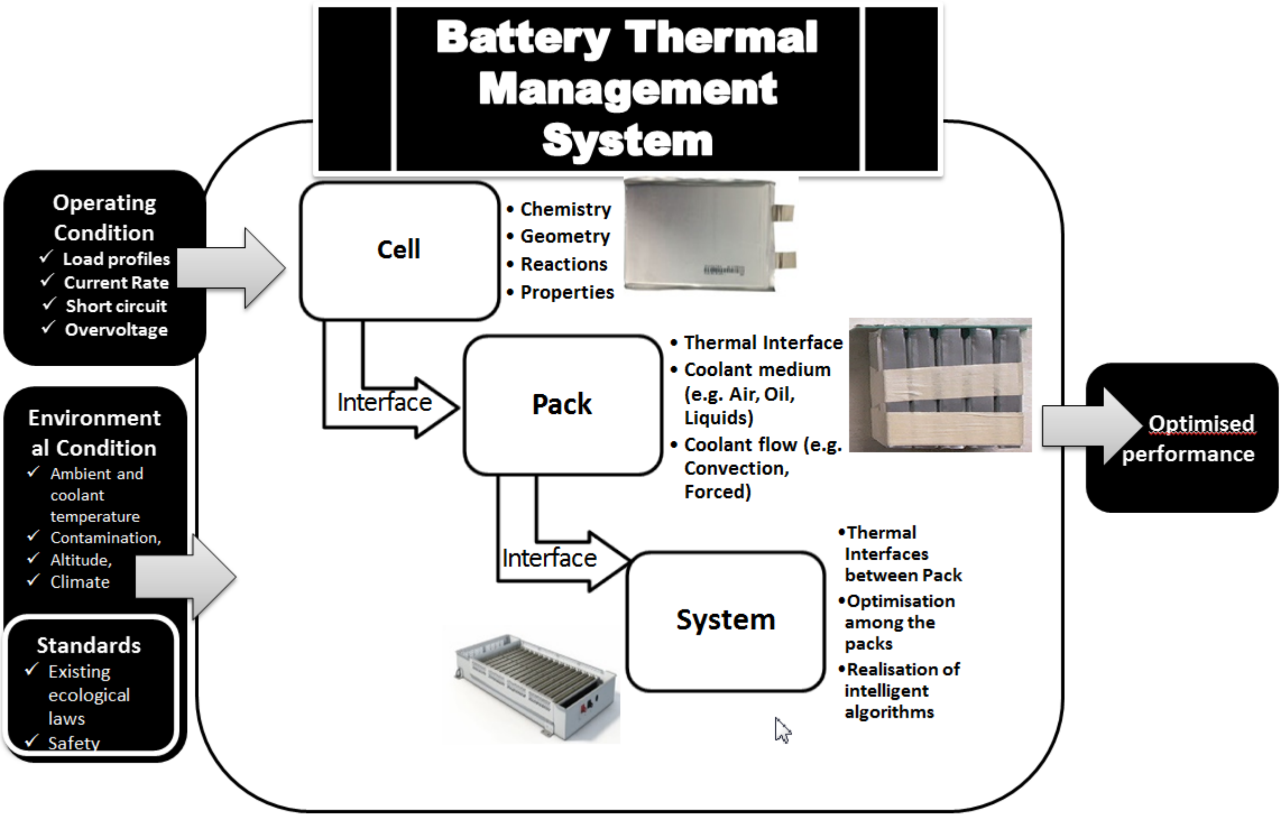

Fig. 1 Battery Thermal Management System.

The thermodynamics of battery cells are complicated by the presence of liquid electrolyte mixtures as well as single-phase and multi-phase solids. Heat generation may originate from mixing and phase change, moreover the main electrochemical reactions and the side reactions. Measurements of temperature rise and heat dissipation of small cells are essential for simple but accurate operation of scaled-up batteries [6].

A battery system's temperature changes from its initial value because of internal heat generation due to electrochemical reactions and resistance or joules effect (heating due to internal resistance), state of charge (SoC), open circuit voltage (OCV), power and ageing level [7,8]. Depending on the operating and ambient condition, the employed method inside BTMS can either be cooling, heating or insulating. A traditional BTMS include air as the medium, electric blower or fan to mobilize the medium. On the other hand, liquid BTMS may include water, glycol, oil, acetone, refrigerants, and phase change materials (PCM) thermal management systems), active or passive approaches, or a combination. In order to ensure uniform, adequate cooling BTMS is composed of controller and controller algorithm that varies different cell's temperature and operational condition. The intensity, direction of cooling, heating or insulation will depend on the specific application requirement. The cooling scheme has to be activated when the battery is exposed of high rate of charge and discharge that corresponds to highly varying current requirements e.g. speed of electric vehicles. Electric heating is responsible for raising battery temperature from ambient cool temperature to desired temperature before system start-up for example in subzero temperature condition. Thermal insulation is needed in case of reducing the heat loss from high temperature either during desired application's operation or stand-by. A basic block diagram of BTMS illustrating the basic connections is shown in Fig. 2.

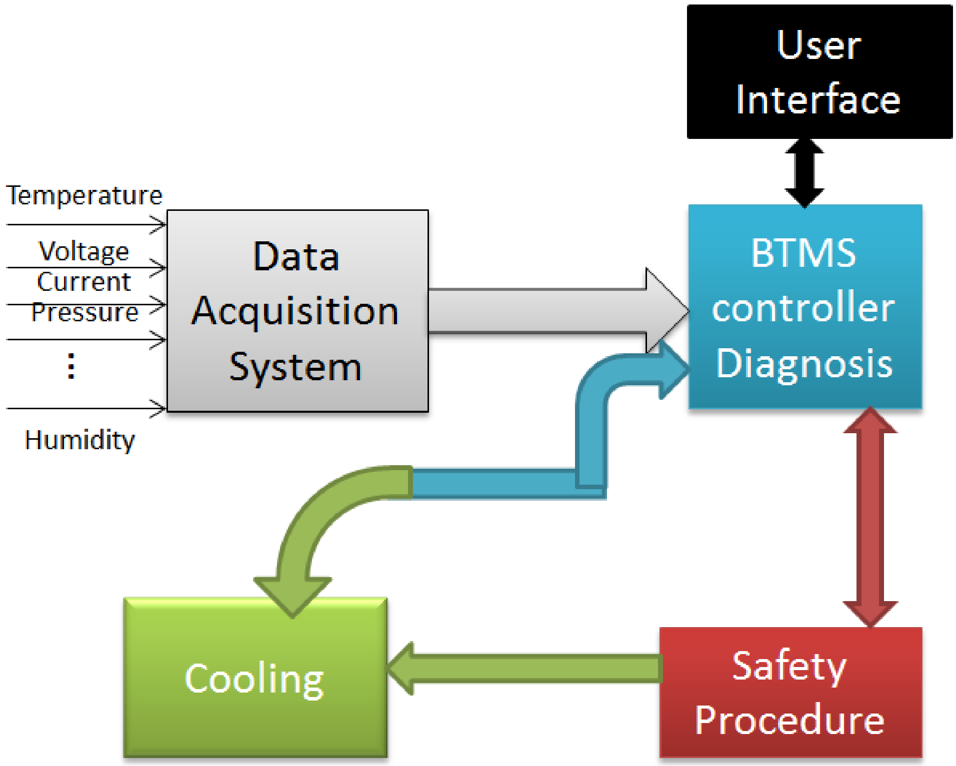

Fig. 2 Components associated with Battery Thermal Management System (BTMS).

To design a good performing battery pack equipped with BTMS, the designer must have the knowledge of the inherent thermal characteristics of cell–pack-systems. To ensure the optimum performance of the battery pack, the thermal management should deliver the following distinctive characteristics:

- ✓ Ensure optimum balanced temperature within a cell
- ✓ Small temperature variation in adjacent cells that the pack is built
- ✓ Tolerable temperature deviation among the different packs in a system level.
- ✓ Control the batteries so that those operate in the desired temperature range; and
- ✓ To reduce uneven temperature distribution between cell, pack and system level.

Each involved approach (i.e. air or liquid cooled BTMS) depends on the availability of information (e.g. power demand, drive cycle, cell shape, materials of construction, battery pack configuration, cost etc.), desire level of sophistication, cost, space and weight limitations.

In order to ensure proper regulation of the battery thermal system performance a number of protective measures are taken into account. In all cases protection from hazards are needed to be priority for any battery stakeholders. All the necessary protection issues are needed to be clearly indicated in the document and needed to be explicitly shown. Fig. 3 contains different protection schemes adopted in the battery system.

Fig. 3 Required protection schemes inside a battery pack.

The most important design parameters for building a BTMS is the cost associated with the particular design and the desired level of the sophistication. The presented features can enhance state of the art BTMS and can make that last longer, reliable, efficient and successful commercial product. In order to ensure the quality of the derived BTMS derived from the standards also require high level of audit and it is perceived that the stake holders must stick to the qualities derived in this publication as well as the application requirement of the battery pack.

Acknowledgments

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