EVERLASTING

Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management

D8.3 – White Paper 01

August 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 713771

Public

PROJECT SHEET	
Project Acronym	**EVERLASTING**
Project Full Title	Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management
Grant Agreement	**713771**
Call Identifier	H2020-GV8-2015
Topic	GV-8-2015: Electric vehicles' enhanced performance and integration into the transport system and the grid
Type of Action	Research and Innovation action
Project Duration	48 months (01/09/2016 – 31/08/2020)
Coordinator	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK NV (BE) - *VITO*
Consortium Partners	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (FR) - *CEA* SIEMENS INDUSTRY SOFTWARE SAS (FR) - *Siemens PLM* TECHNISCHE UNIVERSITAET MUENCHEN (DE) - *TUM* TUV SUD BATTERY TESTING GMBH (DE) - *TUV SUD* ALGOLION LTD (IL) - *ALGOLION LTD* RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN (DE) - *RWTH AACHEN* LION SMART GMBH (DE) - *LION SMART* TECHNISCHE UNIVERSITEIT EINDHOVEN (NL) - *TU/E* VOLTIA AS (SK) - *VOLTIA* VDL ENABLING TRANSPORT SOLUTIONS (NL) – *VDL ETS*
Website	www.everlasting-project.eu

DELIVERABLE SHEET	
Title	**D8.3 – White Paper 01**
Related WP	WP8 (Dissemination)
Lead Beneficiary	VITO
Author(s)	Klaas De Craemer (VITO)
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Type	Report
Dissemination level	Public
Due Date	M12
Submission date	31 August, 2017
Status and Version	Final, version 1.0

REVISION HISTORY

Version	Date	Author/Reviewer	Notes
V0.1	17/08/2017	Klaas De Craemer (VITO) Lead Beneficiary	First draft
V0.2	21/08/2017	Trad Khiem (VITO)	Minor changes
V0.3	28/08/2017	Review by all partners	Minor changes
V1.0	31/08/2017	Carlo Mol (VITO) Coordinator	Submission to the EC

ACKNOWLEDGEMENT

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LIST OF ABBREVIATIONS AND ACRONYMS

ACRONYM	DEFINITION
BMS	Battery Management System
SOA	Safe Operating Area
SOC	State Of Charge
SOH	State Of Health
CMU	Cell Measurement Unit
MMU	Module Management Unit
PMU	Power Management Unit

1 WHITE PAPER: INTRODUCTION

Try to imagine a life without batteries. For many people this is simply not possible anymore. Every day we use devices which rely on batteries. Just try to imagine a life without a mobile phone? Impossible for many of us. But batteries are not only important for mobile phones. All wireless devices need batteries. Just look around and you will see that batteries are simply everywhere! Sometimes we only realize this when a battery gets empty or breaks down.

Many people see a battery as a commodity product and they don't realize that it is in fact a high tech product. It requires a lot of knowledge to produce a safe and reliable battery. Batteries are available in many different sizes and chemistries and are designed for their specific application. A battery for an electric toothbrush is used in completely different operating conditions than a battery for an electric vehicle.

In every application, the end customer expects an affordable, reliable and safe battery.

The EVERLASTING project (http://everlasting-project.eu/) will develop innovative technologies to improve the reliability, lifetime and safety of Lithium-ion batteries by developing more accurate, and standardized, battery monitoring and management systems. This allows predicting the battery behaviour in all circumstances and over its full lifetime and enables pro-active and effective management of the batteries, which leads to more reliability and safety which enables preventing issues rather than mitigating them.

To raise the awareness of the vital and positive role of battery management systems (BMS), a three-monthly white paper will be written on different BMS topics, aimed at a general technical public. These white papers are a few pages long and will be distributed via the EVERLASTING website and through the partners.

This first white paper will be focussing on "BMS Functions".

2 WHITE PAPER 01: BMS FUNCTIONS

The term Battery Management System (BMS) is often used in the context of stationary or mobile (electric vehicles) energy storage systems. However, there is no general definition on the meaning or the functions of such a system. Usually, a BMS is responsible for monitoring, control and protection of battery cells. The latter can be connected in series or parallel configurations to form modules and packs.

2.1 CELLS, MODULES AND PACKS

Battery cells are typically available in three different packages; cylindrical, pouch and prismatic hard case. Since a single battery cell has a limited useable voltage window and energy capacity (for example 3.7-4.2V and 2.000mAh for a cylindrical lithium cell), they are combined into larger battery packs. This can be achieved by putting cells in series or parallel configurations.

Lithium cells are commonly put in parallel first, thereby creating a 'larger cell'. The completed parallel units are then connected in series, which reduces complexity in terms of pack protection. In the battery industry the number of cells in series is specified first, followed by the cells placed in parallel. For example, in the Nissan Leaf electric car, 2 pouch cells are put in series, and then connected in parallel to create a single "2S2P" battery module of around 7.5V and 488Wh [1]. In turn, 48 of these modules are combined into a 360V battery pack.

2.2 Requirements

Under normal operating conditions the chemical energy in a lithium cell is converted to electrical energy with limited heat development. When the cell is used outside its limits, referred to as the Safe Operating Area (SOA), the conversion can quickly become uncontrolled and exothermic. If more heat is released than the cell housing and cooling system can dissipate, an irreversible thermal runaway occurs, possibly leading to fire and explosion [2], [3]. To attain as high as possible energy density, cells are geometrically stacked close together, exacerbating the problem.

The most important task of a BMS is therefore to provide safety functions such that the cells in a battery pack are not operated beyond their specified limits in terms of voltage, temperature and current.

Due to manufacturing differences and ageing, individual cells will exhibit small differences in capacity or behaviour. Over the lifetime of the battery pack these differences can lead to imbalances between the cells, where one cell has become fully charged while another is not. During charging or discharging the total pack voltage is usually kept within its limits. However, when individual cell voltages are not monitored, some cells could already be operating outside of their specifications before the pack limit is reached and charging or discharging is stopped. Therefore a BMS should be able to monitor individual cell voltages and take appropriate safety actions. Conversely, when individual cells are monitored, the performance of the pack as a whole is determined by the weakest cell. A BMS could provide cell balancing functionality to overcome, in part, the small differences between the cells [4]. In turn, this will improve the battery pack's usage efficiency (*e.g.* driving range in an EV) and lifetime [5].

A second task of a BMS is therefore to extend or improve lifetime and efficiency of a battery.

2.3 Functionality

Following the general requirements from previous sections, specific BMS functions can be categorized into five areas, according to [6]:

1. Sensing and control: The BMS must measure cell voltages, temperatures, and battery-pack current. It must also detect isolation faults and control the contactors and the thermal-management system.
2. Protection: The BMS must include electronics and logic to warn for or protect the operator of the battery-powered system and the battery pack itself against over-charge, over-discharge, over-current, cell short circuits, and extreme temperatures through an attached cooling or heating system.
3. Interfacing: The BMS must communicate regularly with the application that the battery pack powers, reporting available energy and power and other indicators of battery-pack status. Further, it must record unusual error or abuse events in permanent memory for technician diagnostics via occasional on-demand download.
4. Performance management: The BMS must be able to estimate state-of-charge (SOC), preferably for all the cells of the battery pack, compute battery-pack available energy and power limits, and balance (equalize) cells in the battery pack.
5. Diagnostics: Finally, the BMS must be able to estimate state-of-health (SOH), including detecting abuse, and may be required to estimate the remaining useful lifetime of the battery cells and pack.

The 'interfacing' category has a broad scope, as it also covers e.g. the sending of alerts and notifications based on information from diagnostics.

2.4 Architecture

As outlined in section 2.1, a battery consists of three layers: the cell, the module, and the pack.

The resulting physical structure of the battery will mostly determine the architectural choices for implementing a battery management system [7], [8], and each layer will form a subset in the BMS' functions:

- At the lowest layer are the Cell Measurement Units (CMU). Each CMU is connected to an individual cell, or a number of cells connected in parallel, and measures e.g. cell level voltage and temperature and provides balancing functions.
- Above it are the Module Management Units (MMU), grouping multiple CMUs and providing higher level functionality to the top level.
- At the top level is the Pack Management Unit (PMU), which supervises the battery pack and communicates with the application, usually over a CAN bus.

This classification allows to distinguish between three architectural topologies:

1. **Centralized**: In a centralized BMS all three layers are combined in a single entity. The BMS is directly connected to all the cells. Because of the amount of wiring needed, a centralized BMS does not scale very well. Additionally, since the total voltage of the pack is present at the inputs, such cases make it difficult to meet isolation requirements.
2. **Modular**: In a modular BMS, multiple MMUs (with their own number of CMUs) communicate with a single, central PMU. The MMUs are close to the cells, reducing the wiring complexity. The MMU communicate with the central PMU over an isolated interface, avoiding the isolation problems of a centralized BMS. A common variant is when the MMU/CMUs are reduced to a bare minimum of measurement and balancing units ('slaves'), and communicate with a central PMU (the 'master').
3. **Distributed**: In the fully distributed architecture multiple PMUs operate on their own set of cells. They can communicate with but operate independently from each other. In the most extreme case each cell is equipped with a microcontroller that tracks SOC, decides on balancing, cell bypassing, … This topology offers the highest flexibility and scalability, but at a high complexity and cost.

Most commercial BMS's are of the modular topology, as they offer the best compromise between complexity, cost and flexibility.

2.5 Summary

In this white-paper we briefly described the structure of a typical battery pack and the rationale behind the use of a BMS. Because of the inherent safety risks associated with them, the architectural concepts of a BMS were introduced.

For a more extensive description of the functionality and a comparison of available BMS's, we refer to our EVERLASTING Deliverable D6.1, "Analysis of state of the art on BMS" (http://everlasting-project.eu/).

2.6 References

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