Ref. Ares(2026)3009292 - 20/03/2026

HORIZON EUROPE PROGRAMME
TOPIC HORIZON-CL5-2022-D2-01-09

GA No. 101103898

NEXT-generation physics and data-based Battery Management Systems for optimised battery utilisation

NEXTBMS

NEXTBMS - Deliverable report

D2.4 - Scalable physics-based models for BMS and cloud

Funded by the European Union under grant number 101103898. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Funded by
the European Union

Deliverable No.	D2.4	
Related WP	WP2	
Deliverable Title	Scalable physics-based models for BMS and cloud	
Deliverable Date	2025-11-30	
Deliverable Type	REPORT	
Dissemination level	Sensitive – member only (SEN)	
Author(s)	Igor Mele (UL), Klemen Zelič (UL), Samo Penič (UL), Tomaž Katrašnik (UL)	2026/03/16
Checked by	Pankaj Pallewar (AVL)	2026/03/19
Reviewed by	Róbinson Medina, Feye Hoekstra (TNO)	2026/03/17
	Sajib Chakraborty (VUB)	2026/03/17
Coordinator	Hansjörg Kapeller (AIT)	2026/03/20

Document History

Version	Date	Editing done by	Remarks
V1.0	2026/03/16	Igor Mele, Klemen Zelič, Tomaž Katrašnik (UL)	Initial version
V1.1	2026/03/17	Róbinson Medina (TNO), Feye Hoekstra (TNO), Sajib Chakraborty (VUB)	Revision
V2.0	2026/03/18	Igor Mele, Klemen Zelič, Samo Penič, Tomaž Katrašnik (UL)	Addressing comments/suggestions from the reviewers
V2.1	2026/03/18	Igor Mele (UL)	Cleaned document
V3.0	2026/03/20	Hansjörg Kapeller	Submitted

Project summary

NEXTBMS will develop an advanced battery management systems (BMS) built on fundamental knowledge and experience with the physicochemical processes of lithium-ion batteries, which will enable the significant enhance of current modelling approaches, including the readiness for upcoming lithium (Li) battery material developments. These modelling approaches will be further improved by optimising sensors and measurement techniques to meet modelling needs (and optimising models based on physical sensor data) and the physical cell configurations to form a framework that supports improving the battery state prediction and -control. By solving these challenges, NEXTBMS will ensure that the next generation of BMSs will enable higher performance, safety, and longer lifetime of the battery cells for an overall optimal utilisation of the battery system.

Publishable summary

Deliverable presents a development of a scalable physics-based modelling framework for battery management, capable of adapting its modelling depth to two specific application domains: a computationally efficient electrochemical model for use on embedded hardware for on-board battery management systems (BMS), and a higher-fidelity electrochemical model with additional sub models for cloud-based applications. The NEXTBMS framework, featuring these two levels of modelling depth, enables monitoring of internal states and parameters of the battery cell, which brings significant advantages over currently used BMS models which are mostly based on the equivalent circuit models. This key benefit of physics-based modelling arises from the physics-based representation of transport and electrochemical processes, material properties, and cell geometry within the model structure, governing equations, and parameterization, thereby improving physicochemical consistency. Therefore, the electrochemical model, which models coupled intra-cell phenomena, including the transport of charged species, electric potential distributions, electrochemical reactions, heat generation, and degradation mechanisms, represents advanced virtual sensors of-intra cell states and parameters, which opens new monitoring and diagnostic capabilities.

Development of the computationally efficient electrochemical model for the BMS was dictated by the selection of the microcontroller unit (MCU) for the BMS, i.e. AURIX™ TC375 from Infineon 32-bit multicore microcontroller based on Infineon's TriCore™ architecture designed for a real-time embedded systems such as automotive and industrial applications. The computationally efficient electrochemical model was developed and successfully flashed to the MCU and performs in real time (RT) capable mode with relatively moderate numerical discretisation with RT factor of 0.2 on AURIX™ TC375. This performance enables the model to function as a real-time high frequency virtual sensor for internal battery states, providing real-time access to otherwise unmeasurable quantities. The availability of this information enables the development and optimisation of advanced control strategies for fast charging and in process avoiding undesirable side reactions such as lithium plating and degradation of active material.

In contrast to the BMS realisation of the electrochemical model, the cloud realisation of the electrochemical model focuses more on the detailed diagnostic procedures that will give insight into the current state of the battery based on the various electrochemical measurements, such as (dis)charge curves, electrochemical impedance spectra (EIS), etc, and, hence, in addition to virtual sensing of intra-cell states focuses also on virtual sensing or monitoring intra-cell parameters. Consequently, this realisation of the model features additional sub-models and diagnostic procedures that will support the analysis of the battery states by extracting the physics-based parameters. Some of the developed features for the cloud model include the following. Virtual EIS diagnostic procedure was developed where the galvanostatic excitations are applied at the current collector interfaces as a boundary condition and the real and complex part of impedance are calculated in from these data. For assessment of the uniqueness of parameter identification, the Fisher information method was used as a tool to assess the uniqueness of model parameterisation and was developed as a standalone library to work seamlessly with the developed electrochemical models.

The generic model structure of both realisations of the electrochemical models enables easy adaptation to Li-ion and future chemistries and for degraded cells by accommodating model parameters. This is a key of prerequisite for supporting novel battery management functionalities for a wide range of cell chemistries and the entire range or relevant operating conditions.

Detailed electrochemical model based diagnostic procedures enables obtaining detailed intra-cell insight into state and parameter variation, whereas it is associated with high computational costs. To tackle this challenge, we have developed also a computationally optimized state of health (SoH) algorithm, which uses only OCV data, and estimates Loss of lithium inventory and Loss of active material with high computational efficiency. These data provide more insight than observation of SoH variation only.