Battery management by multi-X digital twins

Antonios Tzionis
RTD-TALOS Ltd

Adobe Stock © KanawatTH

The world faces a major challenge in reducing greenhouse gas emissions. The transport sector is responsible for approximately a quarter of total greenhouse gas emissions in the EU. Road transport is the largest contributor within the sector, accounting for almost a third of Europe's transport-related emissions. Globally, transport and energy sectors together account for around 40 % of total emissions, making the transition from fossil fuels to green energy increasingly important. Batteries are an important part of the work programme for cross-sectoral climate transition, enabling progress in zero-emission mobility and the expansion of renewable energy. BATMAX aims to pave the way for an advanced next-generation data-based and adaptable battery management system that can meet the needs and requirements of a wide range of mobile and stationary applications and use cases.

Traditional battery manufacturing is highly complicated, as it involves multiple interconnected parameters that affect battery performance, safety, cost, and durability throughout their life cycle. Physics-based models offer high accuracy, but their parameterisation is both time-intensive and expensive. In addition, they are too computationally complex for efficient use in digital twins and battery management systems. The BATMAX project will tackle these challenges by introducing a framework for the efficient parameterisation of physics-based models that allows online parameter updates, alongside reduced-order models suitable for real-time applications.

As BATMAX enters its final months, the project has already achieved important progress across several of its key areas of work. What started as an ambitious effort to advance battery management systems through modelling, sensorisation, artificial intelligence, and digital twin approaches is now taking shape through concrete technical developments. Progress across key areas shows how the project is moving from concept to implementation, with results that bring BATMAX closer to its overall objectives.

Multi-scale physics-based modelling framework, parameterisation

Significant progress has been made in BATMAX's model development work. Among the advances achieved so far are P2D and P4D models for the BATMAX cells, capable of reproducing experimental data at cycling rates of up to 2C with an accuracy exceeding 96 %. At the same time, work has continued on the development and integration of cycle and calendar ageing models within the open-source BattMo framework, helping to predict and explain how cell performance evolves over time. This contributes directly to the project's ambition to model battery behaviour accurately over 500 cycles at different rates. Progress has also been made in safety-related modelling, with the development of a comprehensive State of Safety model incorporating overcharge characteristics under different temperature and pressure conditions, based on experimental data generated within the project. This is now being further advanced through its integration into a Remaining Useful Life tool.

Data, surrogate models, and AI

BATMAX has also made substantial progress in the areas of data management and data fusion. With all planned cycling experiments either completed or approaching completion, the project has built a growing body of experimental data that is being continuously preprocessed and made available through the data portal to support model development. Drawing on these datasets, data-based and surrogate models have been developed to estimate key battery states, including state of charge, state of health, state of temperature, and state of safety. These models are now being further adapted and optimised to improve performance and support their integration into the BATMAX digital twin.

Digital twin and framework validation

BATMAX has made notable progress in both its digital and physical development activities. A cloud-based data platform has now been established and is being used by 26 users across 4 organisations, providing access to 19 shared datasets along with stable preprocessing tools for battery cycling data. At the same time, several digital twin models have been developed and tested, while the project's physical prototype has been designed and assembled, incorporating advanced sensors and an IoT-native battery management system.

Experimental test matrix and prototyping

Battery cycling activities have continued to progress, providing additional data to support ongoing technical development. At the same time, work on prototyping fabrication has moved forward through close co-ordination and technical exchange, helping to define the interfaces between components and lay the groundwork for assembly. The work

has also led to the development and testing of 2 laboratory-scale battery system prototypes, which are being used to demonstrate the project's digital twin framework and validate the advanced battery management methods developed within BATMAX.

Application requirements, regulations, use cases, operation data

Alongside its technical progress, BATMAX has also moved forward in defining its longer-term strategic direction. A battery roadmap has been developed to provide a clear perspective on future advances in battery technologies, while ongoing collaboration across the consortium has strengthened the shared understanding needed to support the effective exploitation of the BATMAX framework. This exchange is helping ensure that the project's strategic outcomes are closely connected to its wider development.

Looking ahead

As the BATMAX project progresses toward completion, the next phase will focus on consolidating the results achieved so far through further integration, testing, and validation. With important advances already made across its main areas of work, the project is now well placed to demonstrate the effectiveness of its digital twin framework and advanced battery management methods. In doing so, BATMAX will help pave the way for smarter and more sustainable battery technologies.

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

PROJECT NAME

BATMAX BATTERY MANAGEMENT BY MULTI-DOMAIN DIGITAL TWINS

PROJECT SUMMARY

BATMAX is an EU-funded project which sets out to pave the way for advanced next-generation data-based and adaptable battery management systems (BMS), capable of fulfilling the needs and requirements of mobile and stationary applications and use cases. The main objective of the project is to contribute to improving battery system performance, safety, reliability, service life, and lifetime cost.

PROJECT PARTNERS

BATMAX is powered by a highly skilled consortium combining expertise in battery technology, AI, digital twins, and industrial manufacturing. The consortium includes leading research institutions, battery manufacturers, technology providers, and software developers. This strong collaboration ensures that BATMAX's innovations are not just theoretical but are deeply embedded into actual European battery production facilities, making them highly scalable and impactful.

PROJECT LEAD PROFILE

VTT is one of Europe's leading research institutions, owned by the Finnish state. They advance the utilisation and commercialisation of research and technology in commerce and society. Through scientific and technological means, they turn large global challenges into sustainable growth for businesses and society. They bring together people, business, science, and technology to solve the biggest challenges of our time.

PROJECT CONTACTS

Project Co-ordinator: Dr Mikko Pihlatie
Research Professor, VTT

Mikko.Pihlatie@vtt.fi
www.batmaxproject.eu
/showcase/batmax-project/
@batmaxprojecteu

FUNDING

Funded by the European Union

Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them. Grant agreement: 101104013.

DISCLAIMER

Article co-ordinated and written by RTD-TALOS on behalf of BATMAX.