
**EPE'23 ECCE Europe – Call for Tutorials**

# Intelligent BMS

## Name(s) and Affiliation(s) of the Lecturer(s):

**Remus Teodorescu**
**Aalborg University**
Pontoppidanstræde 101
Aalborg, Denmark
E-Mail: ret@energy.aau.dk
Phone: +45 99409249

**Dirk Uwe Sauer**
**RWTH Aachen University**
Campus-Boulevard 89
Aachen, Germany
E-Mail: dirkuwe.sauer@isea.rwth-aachen.de
Phone: + 49 241 80 96977

**Changfu Zou**
**Chalmers University of Technology**
Hörsalsvägen 11
Göteborg, Sweden
E-Mail: changfu.zou@chalmers.se
Phone: +46 317723392

**Xin Sui**
**Aalborg University**
Pontoppidanstræde 101
Aalborg, Denmark
E-Mail: xin@energy.aau.dk
Phone: +45 99409249

**Weihan Li**
**RWTH Aachen University**
Campus-Boulevard 89
Aachen, Germany
E-Mail: weihan.li@isea.rwth-aachen.de
Phone: +49 241 80 49415

**Yang Li**
**Chalmers University of Technology**
Hörsalsvägen 11
Göteborg, Sweden
E-Mail: yang.li@chalmers.se
Phone: +46 317721557

## Tutorial Objectives:

The objective of this tutorial is to define the future battery management system (BMS) capable of fast charging, health management and increased safety. This will be based on an intelligent platform able to estimate and predict the battery states (SOH, SOT), physics-informed neural network (NN) modelling, digital twins, addition of actuators in the form of bypass at cell level health management, and risk assessment.

## Target Audience:

The targeted audiences are:

1) University researchers who are interested in battery state estimation and application of machine learning in various electrical engineering fields for this purpose;
2) University researchers who are interested in the smart battery concept, structure, and application of artificial intelligence in future BMS;
3) System designers and developers from the battery industry seeking to understand battery performance degradation, modelling, health diagnostics and prognostics, fast charging technology, and battery control.


**Topical Outline:**

**Introduction: (10 minutes)**

**Theme 1 - Smart Battery (60 minutes)** **Prof. Remus Teodorescu**

- Concept of Smart Battery
- Structure
- Applications

**Theme 2 - AI for state estimation (60 minutes)** **Dr. Xin Sui**

- Lithium-ion battery basics
- Battery aging characteristics and performance parameters
- SOX (SOC, SOT, SOH) estimation using AI
- Short-term and long-term SOH prediction using AI

**Theme 3 - AI for battery aging diagnostics and prognostics (60 minutes)** **Dr. Weihan Li**

- Battery digital twin
- AI for battery aging diagnostics
- AI for battery lifetime prediction
- AI for ageing-aware operation strategy

**Theme 4 - AI for battery fast charging (60 minutes)** **Prof. Dirk Uwe Sauer**

- Electrochemical model basics
- State estimation for fast charging
- Parameter identification for ageing-aware fast charging
- Fast charging strategies with AI

**Theme 5 - AI for physics-based battery modelling (60 minutes)** **Assoc. Prof. Changfu Zou**

- State-of-art battery models
- Architecture of model-integrated neural networks (MINN)
- MINN for control-oriented battery modelling
- Other possible applications of MINN

**Theme 6 - Grid-interfaced battery control (60 minutes)** **Assoc. Prof. Yang Li**

- Generic mutliphysics-based equivalent circuit models
- Model inversion-based battery charging/discharging control
- Health-aware grid-interfaced EV battery control for V2G services

**Q&A (30 minutes)**

**Provisional Schedule of the Tutorial:**

Schedule:

09:30 - 13:00: Introduction / Theme 1 / Theme 2 / Theme 3
13:00 – 14:00: Lunch Break
14:00 – 17:30: Theme 4 / Theme 5 / Theme 6 / Q&A

## About the Lecturers:

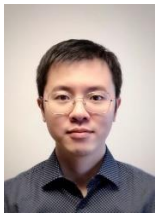
**Remus Teodorescu** received the Dipl.Ing. degree in electrical engineering from the Polytechnical University of Bucharest, Bucharest, Romania, in 1989, Ph.D. degree in power electronics from the University of Galati, Romania, in 1994 and , Dr.HC in 2016 from Transilvania University of Brasov. In 1998, he joined the Department of Energy Technology at Aalborg University where he is currently a Full Professor. Between 2013 and 2017, he has been a Visiting Professor with Chalmers University. He is IEEE/PELS Fellow since 2012 for contributions to grid converters technology for renewable energy systems. In 2022 he became a Villum Investigator and leader of Center of Research for Smart Battery (CROSBAT) at Aalborg University. His main current research areas are: Modular Multilevel Converters (MMC) for HVDC/FACTS, Li-Ion battery SOH Estimation with AI and Smart Batteries.

**Dirk Uwe Sauer** is the professor for the Chair for Electrochemical Energy Conversion and Storage Systems at the Institute of Power Electronics and Electrical Drives (ISEA) at RWTH Aachen University for 19 years. He is a specialist in all aspects of system integration of batteries, incl. testing, characterization, ageing, modeling, diagnostics, lifetime prediction and field integration into any type of mobile or stationary applications. His chair has about 75 full-time employees and more than 60 students as student assistants, or in bachelor or master thesis. He is a member of the National Academy of Science and Engineering (acatech) and the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW). He is also the co-founder of 4 spin-off companies.

**Changfu Zou** is an associate professor and the PI of the Energy Systems and Optimal Control (eSOC) Lab at the Department of Electrical Engineering, Chalmers University of Technology, Sweden. His research focuses on modelling and optimal control of energy storage systems, particularly batteries. Many of his works are in collaboration with industry partners, such as Volvo Cars, Volvo Trucks, Scania, Polestar, and CEVT. As the project manager, he has received several prestigious grants from European Commission and Swedish national agencies and has hosted three Marie Skłodowska-Curie Fellows. He serves as an editor/editorial board member of four top journals and has been a reviewer of a number of research grants, e.g., for the Horizon Europe, US National Science Foundation, and Academy of Finland.

**Xin Sui** received the B.Eng. degree from Northeast Electric Power University, Jilin, China, in 2015, and the M.Sc. degree in from Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, China, in 2018, both in electrical engineering. In 2022, Xin received the Ph.D. degree in machine learning for battery state of health estimation from Aalborg University, Aalborg, Denmark. She is currently a postdoctoral researcher with the Center for Research on Smart Battery (CROSBAT), AAU Energy, Aalborg University. Her research interests include battery state of health estimation, lifetime extension, feature engineering and machine learning.

**Weihan Li** is the head of the young research group "Machine Learning for Batteries" at RWTH Aachen University since 2022. During 2018 – 2021, he was team leader and research associate at the Chair for Electrochemical Energy Conversion and Storage Systems of RWTH Aachen University, Germany. He received his Ph.D. (electrical engineering) with the highest praise "summa cum laude" at RWTH Aachen in 2021, M. S. (automotive engineering) at RWTH Aachen in 2017 and B. S. (automotive engineering) at Tongji University in 2014. During 2016 – 2017, he was a visiting research assistant at the Massachusetts Institute of Technology (MIT), USA. He was also with Volkswagen AG and Porsche Engineering GmbH in various electrical and mechanical engineering roles. The research interests of Weihan Li's group include the modeling, testing and control of batteries from the material level to the system level with a wide application of physics-based and machine learning approaches.



**Yang Li** received the B.E. degree in electrical engineering from Wuhan University, Wuhan, China, in 2007, and the Ph.D. degree in power engineering from Nanyang Technological University (NTU), Singapore, in 2015. From 2015 to 2020, he was a Research Fellow with the Energy Research Institute, NTU, a Research Fellow with the School of Electrical Engineering and Computer Science, Queensland University of Technology, Brisbane, QLD, Australia, and an Associate Professor with the School of Automation, Wuhan University of Technology, Wuhan, China. He is currently a Researcher with the Department of Electrical Engineering, Chalmers University of Technology, Gothenburg, Sweden. His research interests include modeling and control of battery systems for power grid and transportation sectors. Dr. Li was a recipient of the EU Marie Sklodowska-Curie Action Individual Fellowship in 2020. He serves as an Associate Editor for several top-tier journals in his research area, such as IEEE Transactions on Industrial Electronics and IEEE Transactions on Transportation Electrification, and was a Guest Editor for Elsevier's Applied Energy.