PhD student: Mattia Ribera

Battery modelling for SOH estimation and innovative HESS solution to enhance lifetime of battery-based charging station

Tutor: Prof. Diego Iannuzzi

Cycle: XXXVIII Year: I

My background

Before PhD:

- Master's degree in Automation Engineering at the University of Naples Federico II
- Master's degree thesis on EV charge scheduling for UFCS
- Designed a Control firmware for a DC-DC converter for EV mobile charger

PhD course:

- PhD start date: 01 November 2022
- Scholarship type: UNINA
- Electrical engineering group (CRIAT group)

Research field of interest

- The research activities are focused on electrochemical storage systems, particularly based on lithium technology.
- Activities range from battery modeling, useful for defining efficient algorithms for estimating important cell parameters, to intelligent smart grid applications to achieve the best performance for both energy efficiency and better lifetime of energy storage system.

Summary of study activities

- Ad hoc PhD courses :
  - Statistical data analysis for science and engineering research
  - Percorso per il rafforzamento delle competenze sulla progettazione europea
- Courses borrowed from MSc curricula:
  - Generatori, Convertitori E Dispositivi Di Accumulo *(Electric generator, Converters and Energy Storage System)*
  - Electric And Hybrid Vehicles

Summary of study activities

- Conferences attended:
  - Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles (ESARS) and International Transportation Electrification Conference, March 2023 *(presenting author)*
  - IEEE Vehicle Power and Propulsion Conference (VPPC), October 2023 *(virtual as presenting author)*
- Event attended:
  - i-STENTORE 1° Plenary meeting and ESWDays Project Event, June 2023 *(as speaker of Italian Demo of the european project)*

Research activity

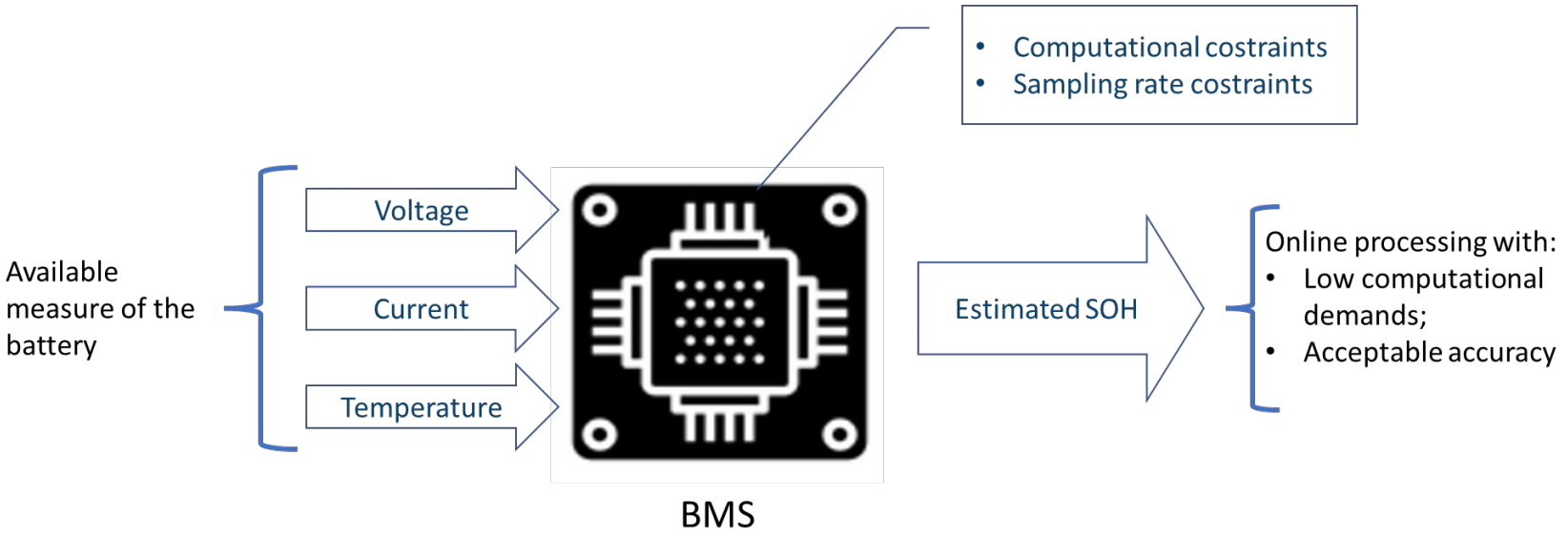
1. *Research on battery modelling techniques for the purpose of State of Health estimation*
2. *Benefits of hybrid storage systems for charging stations based on lithium battery technology*

Battery modelling and SOH Estimation: Overview

- ***Problem***

Battery degradation occurs both during stationary time periods and operation depending on several stress factors. The amount of available charge left of a battery during its operative life corresponds to the State of Health (SoH) of battery.

The main problem is, how to estimate SOH levels for embedded solutions.



Battery modelling and SOH Estimation: Overview

- ***Objective***

The research activity goal is to define a good modelling approach to characterize a lithium battery at different ages and provide an SOH estimation algorithm.

- ***Methodology***
  - Linearize the battery at fixed operating conditions (SoC, SoH and temperature) and store the models in a database;
  - Compares the reconstructed behaviour to the measured behaviour and evaluate the goodness of fit for the estimation

Battery modelling and SOH Estimation: Overview

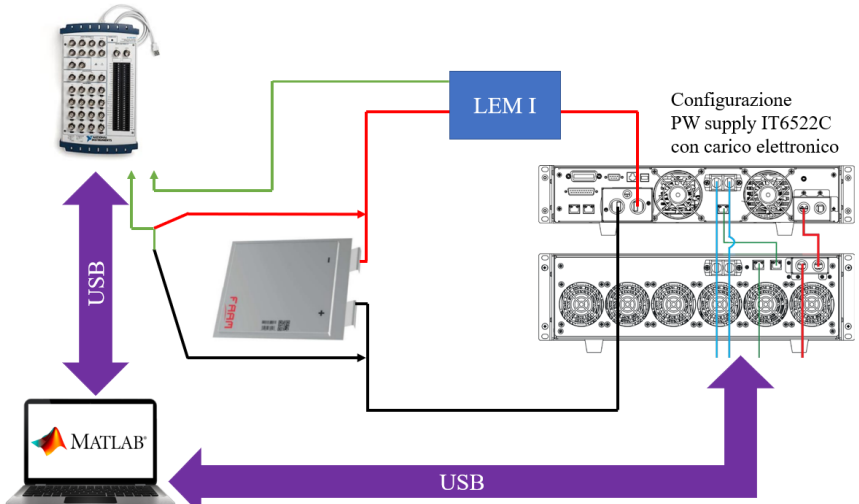
- ***Methodology: Test bench***

Climate chamber: Discovery ACS DM600ESP

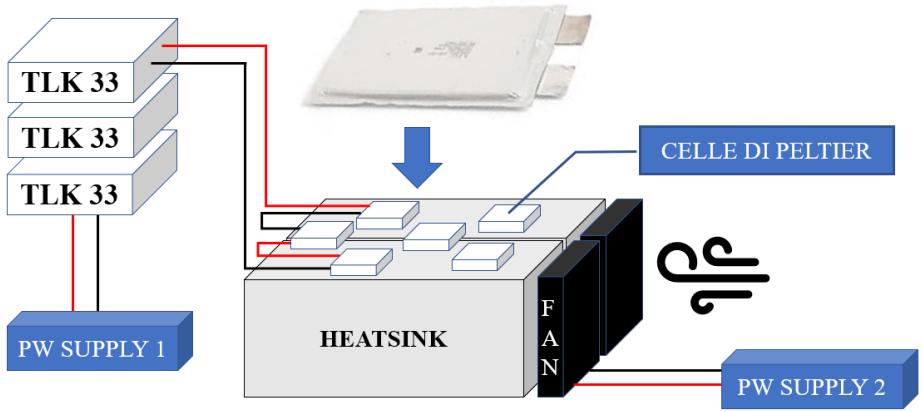
Battery cycler: ACT0550

FAAM

Battery cycler

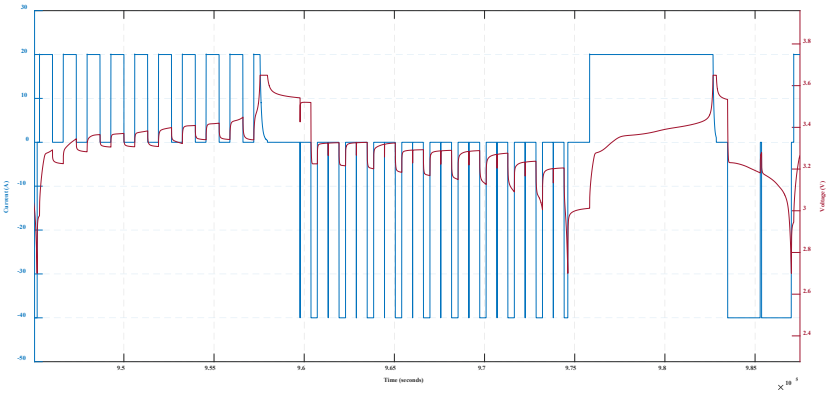


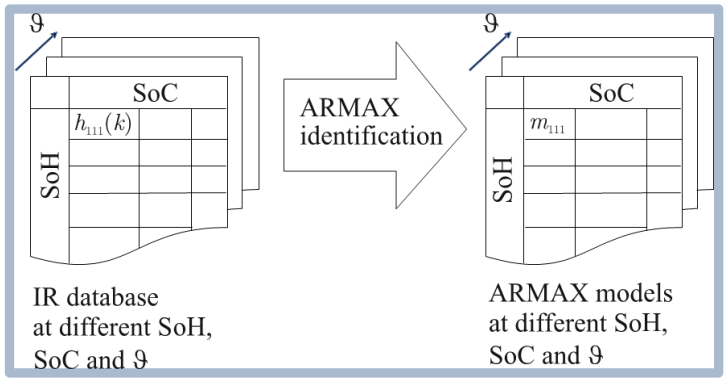
Thermoelectric controller

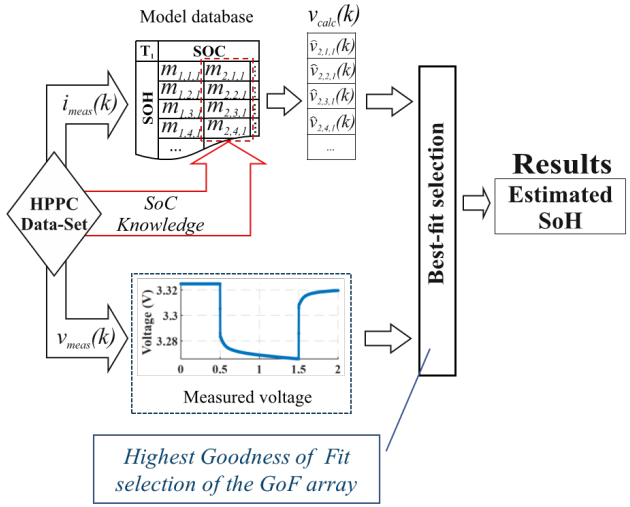


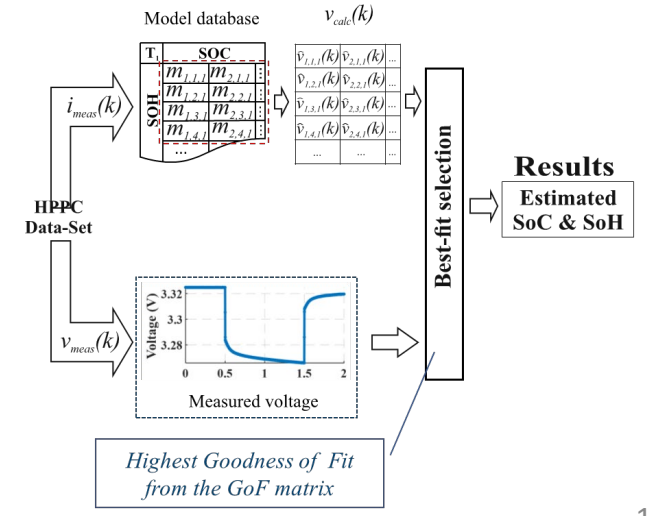
Battery modelling and SOH Estimation: Overview

- ***Methodology***









Battery modelling and SOH Estimation: Overview

- ***Results and conclusion***

➢ Preliminary results show that the algorithm can jointly estimate SOH and SOC of the cell in some operating conditions, for example, wrong SOH estimation are associated with intermediate SOC levels. However, the experimental campaign requires more time to obtain more data for a more accurate analysis of the effectiveness and accuracy of the method.

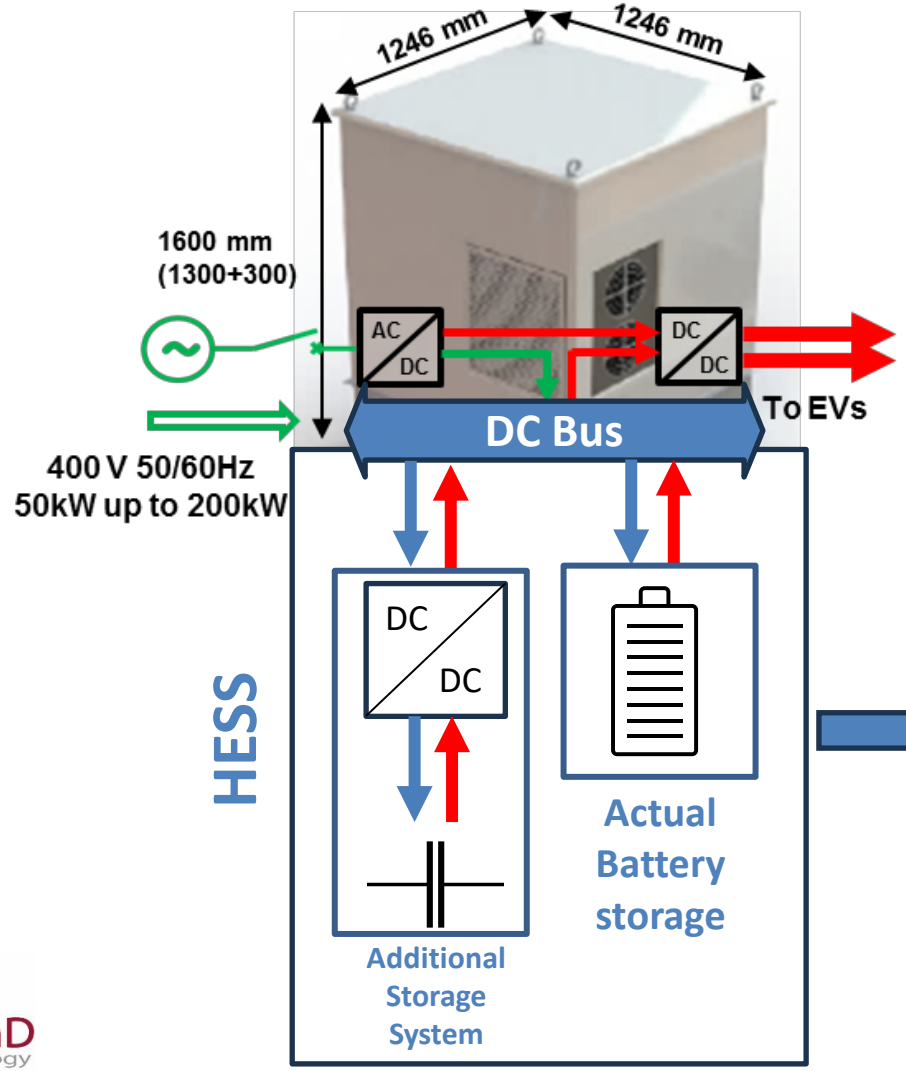
➢ Meanwhile, a new test bench in UNINA lab will be developed with a more performant and robust thermal control.

➢ Different modelling techniques (e.g. Neural Network model) are taken into account

HESS for charging station: Overview

- ***Objective***

The research activity goal is to define the benefits of hybrid energy storage system for the actual Ultra Fast Charging Station



Main features
• Input : Public Electrical Network (50kW up to 140 kW) • Input : PV up to 100kW
• Integrated storage battery 158 kWh, to deliver large power to the Electric Vehicles: up to 320 kW
• Output current to Electric Vehicles up to 400 A
• Ambient temperature: -20 °C / +45 °C
• Low acoustic noise
• Easy access for high maintainability

Potential Innovation

- Hybrid Energy Storage cost saving;
- Extended NMC batteries lifetime for E-Mobility Service;
- HESS flexibility solution for E-mobility, Logistic and Residential Market;

HESS for charging station: Overview

- ***Methodology***

1) Define good models of the actual and new energy storage systems to evaluate in simulation the capacity degradation during EV charging routines;
2) Define an optimal energy management to extend the lifetime of the HESS;
3) Implement and test the upgraded ultra-fast charging station

Products

[C1]	D. Iannuzzi; M. Ribera; P. Satariano; E. Fedele; F. Pagliarini; P. Cennamo; F. Orsini; L. Petrazzuoli; M. Spinelli *"Capacity Fade Estimation of LiFePo Cells Based on Improved Impulse Response Method: Experimental Results"* 2023 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC), Venice, Italy, March 2023
[C2]	P. Franzese; M. Ribera; D. Iannuzzi *"Design Comparative Analysis Of Distributed and Concentrated Electrical Power Conversion Systems for Multi-Slot Ultra-Fast Chargers"* 7th E-Mobility Power System Integration Symposium, Copenhagen, Denmark, September 2023
[C3]	S. Barcellona; S. Colnago; E. Fedele; D. Iannuzzi; L. Piegari; M. Ribera *"Cycle Aging Effect on the Open Circuit Voltage of a LiFePO4 Battery"* 2023 IEEE Vehicle Power and Propulsion (IEEE VPPC 2023), Milan, Italy, October 2023

Thank you for your attention

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