

**Ph.D. in Information Technology
Thesis Defense**

**April 8th, 2026
At 5:00 p.m.
Meeting Room PT2 – Building 20A**

Andrea TRIVELLA – XXXVIII Cycle

ADVANCED MODELING AND STATE ESTIMATION FOR BATTERY MANAGEMENT SYSTEMS

Supervisor: Prof. Matteo Corno

Abstract:

The rapid electrification of transport is intensifying the demand for lithium-ion batteries that are high-performing, reliable, and safe. For electric vehicles and aerospace applications, Battery Management Systems (BMSs) and system design must rely on predictive, physics-aware models and experimentally validated algorithms to enable optimal battery sizing, robust online monitoring, and mission-level assurance.

This doctoral dissertation, presented as a collection of peer-reviewed and draft articles, advances modelling, estimation, and model-based decision tools for Li-ion batteries targeted at high-performance and safety-critical applications. The thesis is organised along three complementary axes. The first axis develops models and experimental identification protocols for a broad range of battery dynamics: electrochemical, thermal and ageing. For the electrochemical work, non-invasive identification strategies are proposed for reduced Single Particle Models (SPMs) applied to different cells; these models outperform classical equivalent-circuit models (ECMs) in prediction and provide insight into otherwise unobservable internal states. The thermal work focuses on a prototypical high-power pouch cell for e-racing applications and spans models of increasing fidelity (from lumped to 2-D distributed), tailored identification protocols and tools for numerical stability analysis. Finally, ageing is experimentally characterised on a cell selected for an eVTOL application: an empirically calibrated cycle-ageing model is used to predict battery-pack lifetime under repeated mission profiles. The second axis focuses on real-time estimation. Two contributions are included: a new second-order sliding-mode algorithm applied to State of Charge (SoC) estimation, demonstrating strong robustness and accuracy; and a particle-filter algorithm for joint SoC/State of Health (SoH) estimation, calibrated on pre-aged cells and validated with good performance across varied operating conditions.

The third axis addresses applied design problems in powertrain and battery-pack sizing for helicopter applications. Two studies are presented at increasing levels of maturity: a methodology for preliminary conceptual sizing of a hybrid-electric powertrain for a light helicopter/UAV, and a pack-optimization method driven by experimental characterisation of promising cells and validated through mission-scaled testing, yielding practical insights for integration and thermal–durability trade-offs.

These contributions combine experimental analysis, physics-based modelling and the development of estimation and decision algorithms to improve battery monitoring and the design of electric

propulsion systems. The resulting model-based techniques can help create more efficient, higher-performing and safer systems, and support the electrification of vehicles.

PhD Committee

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