POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

THEMATIC Research Field: ADVANCED BATTERY MANAGEMENT SYSTEMS AND STRUCTURAL BATTERIES FOR NEXT-GENERATION ENERGY SOLUTIONS

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The efficient management and innovative application of battery systems are crucial for the advancement of sustainable energy technologies. Battery management systems (BMS) and structural batteries are pivotal in optimizing energy storage and usage in various engineering systems, including automotive, aerospace, and renewable energy sectors. The primary goals in this field involve ensuring battery safety, enhancing performance, extending lifespan, and reducing costs and environmental impact. The frameworks for assessing the health of battery systems include the following steps: •Degradation Diagnosis: Identifying, quantifying, and locating degradation within battery cells and systems. •Degradation Prognosis: Predicting the remaining useful life (RUL) of batteries after diagnosing degradation. Health and Usage Monitoring Systems (HUMS) are integral to improving the performance and reliability of battery management systems. These systems enable real-time condition-based and predictive maintenance strategies by utilizing permanently installed diagnostic units for real-time monitoring of battery health. The advent of advanced sensors and data fusion techniques has further enhanced the accuracy of degradation diagnosis and prognosis in battery systems.

	However, the complex data processing required demands robust machine learning (ML) solutions to manage and interpret vast amounts of diagnostic data effectively. Researchers are now focusing on integrating high-fidelity models with advanced ML algorithms to accurately describe the complex dynamics associated with battery degradation and to detect even the smallest deviations from normal operational conditions.
Methods and techniques that will be developed and used to carry out the research	To conduct this research, the Ph.D. candidate will develop high-fidelity and digital twin (DT) models of battery systems. These models will enable numerical analysis of real system behaviors through validated simulations that account for various environmental and operational conditions. Digital twins, serving as virtual counterparts of real battery systems, will typically be multi-physics and include high-fidelity models of subsystems. They will facilitate the acquisition of diagnostic signals through virtual sensor networks, replicating real system behaviors under external stimuli and environmental conditions. The candidate will analyze these signals alongside experimental observations to identify and extract damage-related features. These features will inform diagnostic and prognostic algorithms and aid in developing advanced BMS frameworks. The candidate will train ML algorithms using experimental data, numerical data, or a combination of both, collected under various conditions, including signals representing both healthy and damaged states of the battery systems. The research will establish ML-based frameworks for battery degradation diagnosis and prognosis, incorporating state-of-the-art solutions such as: •Deep Learning •Convolutional Neural Networks (CNNs) •Physics-Informed Neural Networks (PINNs) •Graph Neural Networks (GNNs) •Recurrent Neural Networks (RNNs) •Transfer Learning Explainability techniques, such as Layer-Wise Relevance Propagation (LRP) for CNNs, will be used where possible to ensure the ML algorithms are interpretable.

Educational objectives	The Ph.D. program aims to provide candidates with high-level scientific training, enhancing their research and problem-solving capabilities. By the end of the PhD cycle, the candidate will be able to plan and carry out original research, either independently or as part of a team, in the field of battery management systems and structural batteries. The candidate will develop strong theoretical and experimental skills, with opportunities to collaborate with project partners and spend visiting periods abroad. Specifically, the candidate will gain expertise in: •BMS development and optimization •Performance assessment •Sensor installation, acquisition, and data processing- •Advanced ML algorithms (deep learning, transfer learning, explainability methods, etc.) •Bayesian model identification and updating •Methods for diagnosis and prognosis of battery systems under degradation •High-fidelity system model development (digital twin)
Job opportunities	Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared Master of Science holders in the same field. A recent survey showed that PhD candidates are 100% employed after one year, in national and international companies and academic and non-academic research institutions, engaged in innovation, research and technical development. On average the survey showed that people earning our PhD title obtain 35% higher salary than the corresponding employers with a Master of Science degree. Specifically, the skills and know-how developed during the PhD will allow to cover positions for design, maintenance and integrity assessment of advanced systems and components in aerospace, automotive and mechanical companies.

Composition of the research group	2 Full Professors 2 Associated Professors 0 Assistant Professors 10 PhD Students
Name of the research directors	Proff. Francesco Cadini, Marco Giglio

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of Euro 6.114,50. Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 750 euro/month - net amount). Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.