Ph.D. in Information Technology
Thesis Defenses

May 28th, 2026
At 2:30 p.m.
Sala Conferenze Emilio Gatti - Building 20

Alessandro Del DUCA – XXXVIII Cycle

MANAGING UNCERTAINTY IN REAL-TIME OPTIMISATION AND CONTROL OF POWER GRIDS

Supervisor: Prof. Fredy Orlando Ruiz Palacios

Abstract:

The growing integration of renewable and distributed energy sources is reshaping the global power infrastructure landscape, introducing a complex array of operational challenges. The inherent unpredictability and variability of renewable energy generation, compounded by communication uncertainties and the presence of heterogeneous participants, make optimal power system management increasingly critical.

This thesis addresses these challenges by developing scalable and robust energy management methodologies tailored to power systems comprising a large number of medium-to-low-power assets, including battery storage systems, solar photovoltaic units, and prosumers participating in the energy market through demand response programs.

At its core, this research establishes a theoretical framework for managing uncertainty in distributed multi-agent energy systems. To this end, it integrates scenario-based techniques, distributed and decentralised optimisation, set-membership estimation, and adaptive model predictive control strategies, enabling robust system operation, mitigating performance degradation, and supporting risk-aware decision-making.

The proposed framework supports the design and operation of microgrids, virtual power plants, and flexible load aggregations, ensuring optimal utilisation of available resources and compliance with operational constraints under uncertainty, while emphasising scalability, robustness, and safety.

In summary, this thesis provides advanced tools for designing resilient, adaptive, and efficient energy management systems capable of handling uncertainties in power generation, communication, and model mismatches.

Lorenzo NIGRO – XXXVIII Cycle

SCALABLE MULTI-ENERGY SYSTEMS CONTROL: DESIGN AND EXPERIMENTAL VALIDATION

Supervisor: Prof. Riccardo Scattolini

Abstract:

Climate change and the European Green Deal drive the urgent need to transform how energy is produced, stored, and used. As renewable sources like wind and solar replace fossil fuels, power systems must become more flexible to balance fluctuating supply and demand. This dissertation focuses on Multi-Energy Systems, networks that link electricity, district heating, and other energy carriers to use resources more efficiently and reduce emissions.

The main research goal is to design control architectures that make these interconnected systems operate efficiently, reliably, and sustainably. To achieve this, the work follows three steps. First, it develops accurate yet lightweight models of District Heating Networks (DHNs), a key component of MES, to understand and predict their behavior. Second, it designs a predictive control framework that can coordinate the operation of multiple energy systems, balancing costs and performance. Third, it validates these models and control strategies experimentally on a real test facility, demonstrating their practical effectiveness.

The methodology combines physical modeling, optimization, and control. A detailed DHN simulator is built in Modelica to test and refine control algorithms. A simplified model supports real-time predictive control of interconnected systems. The study then extends to MES coordination, introducing scalable control architectures that can manage several subsystems while preserving privacy and autonomy. Hierarchical and distributed controllers use shared information only when needed, ensuring efficient cooperation among different energy networks.

The results show that the proposed models and control frameworks improve energy efficiency reducing operational costs, preserving privacy, and ensuring profit to subsystems. Academically, this work advances the understanding of control-oriented modeling and coordination in complex energy systems. Practically, it offers tested tools and algorithms that help real-world implementations toward a more flexible, low-carbon energy future. This research demonstrates that scalable and optimal control of multi-energy systems is not only possible, but essential for achieving a sustainable and resilient energy transition.

PhD Committee

Prof. Marcello Farina, **Politecnico di Milano**

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Prof. Alessandra Parisio, **University of Manchester**