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PhD position in Aerospace Engineering

Joint curriculum with the PhD Degree in Information Technology – Systems and Control

Research title: Plant-control Co-Design of Airborne Wind Energy Systems

Motivation and objectives: Airborne Wind Energy (AWE) is the technology of generating wind energy with an autonomous tethered aircraft. It represents a radically new concept for wind energy conversion, deemed a potentially game-changing solution that is attracting the attention of policymakers and stakeholders, including the European Commission, with the promise of producing large amounts of cost-competitive electricity and with wide applicability worldwide. AWE technologies are the subject of research and development by several research groups and small and medium enterprises worldwide, trying to solve the technical bottlenecks that still block the way to commercialization. One such bottleneck is system reliability, where the main challenge is due to the strong interactions between system design aspects, mostly pertaining to aerodynamics, aircraft structure, and flight mechanics, and control design aspects, such as the safe switching among different flight regimes and fault-tolerant control logics. An integrated plant-control co-design of AWE systems would be required to properly address this challenge; however, no research group so far has been able to develop such an approach. The goal of this PhD project is to deliver a rigorous and effective co-design method for AWE and to test it both in high-fidelity simulations and experimentally. This objective is fully consistent with Mission 2 "Green Revolution and Ecological Transition" of the National Recovery and Resilience Plan (PNRR), particularly Component 2 "Renewable Energy, Hydrogen, Grid and Sustainable Mobility." The research is also consistent with Mission 1 "Digitization, innovation, competitiveness, culture and tourism" in its component 2 "Digitization, innovation and competitiveness of the production system" with reference to the production of innovative goods and services for energy generation.

Example of Airborne Wind Energy System, image from "Autonomous Airborne Wind Energy Systems: Accomplishments and Challenges", *Ann. Review of Control, Robotics, and Autonomous Sys.* (2022)

Methods and techniques that will be developed and used to carry out the research: Only an interdisciplinary research effort involving both aerospace and control engineering can successfully deliver the wanted co-design methodology. The PhD student will address the joint plant and control design for different classes of AWE systems, bringing together and deepening the expertise of the proposers. The first year will be focused on deeply understanding the aerodynamic and structural aspects of tethered aircraft, which present a completely different behaviour with respect to conventional aircraft, as well as the current state of the art in automation and control of AWE

POLITECNICO
MILANO 1863

systems, and the links between AWES design and its control. Moreover, a failure mode and effects analysis for this class of systems will be carried out. In the second year, the plant-control codesign approach will be formulated and studied as an optimization problem, drawing inspiration from results obtained by one of the groups in the wind energy sector, and integrating the current aeroelastic design of wind turbines with the preliminary design of the aircraft, as recently proposed for a hybrid-electric aircraft. To concurrently optimize the plant design and its automation and control, an innovative procedure to optimally select and tune the latter will be developed, accounting for the constraints and specifications of all the operational phases (take-off, power generation, transition phases, landing) and aiming to guarantee suitably defined performance indicators of system robustness and reliability, also considering faults and consequent recovery measures studied in the previous year. The third year will be devoted to extensive testing of the developed co-design technique, using detailed simulation suites and partly via experiments in the laboratories of the two proponents). The PhD will spend six months abroad at TU Delft, with whom the research groups have an ongoing collaboration that can be further strengthened by this project, bringing the groups to greater international visibility.

Educational objectives: While developing the research, the PhD student will be required to spend time on the acquisition of highly specialized technical and personal skills oriented toward his or her future entry into the world of employment. The choice of study plan will be made by the PhD student, giving priority to his/her specific interests and the relevance of the chosen subjects to the research work. In addition, possible collaborations with companies in the field of AWE will give the candidate the opportunity to explore the industrial world, thus expanding his or her skills outside the academic world.

Period abroad: the PhD candidate will carry out a period of six months abroad for research collaboration. Possible venues are TU Delft, DTU, UC3 Madrid. Shorter visiting periods at other research groups and/or companies are encouraged, too, compatibly with the research work and results.

Timings and remuneration: the PhD studentship will start on December 22nd, 2023 and will last 3 years. The studentship is 1400,00€ net per month; salary can increase to around 1600,00€ net per month with top-ups and/or paid teaching activities at Politecnico di Milano. During the period abroad, a further amount of 700€ net per month is given for up to six months.

Research funding: research funds will be available to attend PhD schools in Italy and abroad, present at international conferences, carry out the experimental work.

Research environment: The PhD candidate will work with two research groups in the Aerospace Engineering and Automation and Control Engineering fields, see http://www.poliwind.polimi.it/, https://www.sas-lab.deib.polimi.it/ for more information.

Job opportunities: Upon completion of the PhD program, the candidate will have work opportunities either in companies in sectors such as AWE, aerospace, wind energy, automation and control, or at universities and research centers dealing with wind energy research and/or automation and control research.

Requirements: M.Sc. Degree in a relevant engineering or applied mathematics discipline, e.g. mechanical, electrical, automation engineering, numerical optimization.

Selection procedure: the candidate must apply online on the website of Politecnico di Milano, more information is available at this link and here.

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