Université Gustave Eiffel

Research Internship Proposal – TFE Engineer or M2

Advanced MIMO Control of a Three-Phase Modular Multilevel Converter (MMC) for the Integration of Solar Power

Supervisors:

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I. Context and description

In recent years, the global energy landscape has been undergoing a profound transformation. Following the renewed climate commitments highlighted during COP30 in 2025, countries reaffirmed their ambition to limit global warming to well below 2 °C, with a strengthened target of 1.5 °C by mid-century. Achieving these climate objectives requires large-scale decarbonization and the rapid expansion of electricity generation from renewable energy sources (RES) [1][2], mainly solar PV and wind.

However, the high penetration of converter-based RES introduces significant technical challenges. Their intermittent, weather-dependent nature complicates supply-demand balance, causing voltage and frequency fluctuations. Meanwhile, their gradual replacement of synchronous machines reduces system inertia, increasing vulnerability to disturbances. Energy storage systems (ESS, such as battery energy storage systems (BESS), flywheels, or hydrogen solutions), are essential for grid stability and require advanced power electronic interfaces [3]. In this context, the design and control of power converters are therefore crucial for high-RES integration and providing ancillary services, though traditional two- or three-level voltage source converters (VSCs) face limitations at medium and high voltage.

Modular Multilevel Converters (MMCs) have emerged as a powerful alternative thanks to their modular architecture, scalability, low harmonic distortion, and capability for transformer-less medium/high-voltage operation. MMCs are now considered one of the most promising converter topologies for integrating RES and ESS into modern power grids [4]. Nevertheless, their internal dynamic, including circulating currents, capacitor voltage balancing, and strong multivariable interactions, make control design significantly more complex.

To address these challenges, advanced control strategies beyond classical multi-loop PI structures are increasingly necessary. This internship aims to build upon Barresi's thesis [5]**,** which analyzed MMC–PV architectures and balancing strategies, as well as the recent work by Lourenco et al. [6], with the goal of developing a centralized multivariable (MIMO) controller capable of improving the stability and overall performance of MMC–PV systems under realistic operating conditions.

II. Objectives

The main objective of this internship is to develop and evaluate an advanced centralized MIMO control strategy for a three-phase MMC interfaced with PV panels. Building on [5] and [6], the goal is to replace classical multi-loop PI controllers with a single controller capable of handling the strong couplings and internal dynamics of MMCs. Specifically, the internship aims to:

1. Analyze the nonlinear and multivariable dynamics of the MMC–PV system focusing on circulating currents and capacitor voltage balancing.
2. Design a centralized MIMO controller (state-feedback, LQR, MPC, or other suitable techniques) to regulate both internal and external loops.
3. Compare the proposed control with the classical multi-loop PI approaches
4. Evaluate the controller's performance under various operating conditions, including irradiance variations, grid disturbances, and unbalanced loads.

III. Work Plan

The internship will be structured into the following phases:

1. Literature Review
    - Study MMC operation principles and mathematical models.
    - Review classical PI-based control strategies.
    - Analyze Barresi's thesis and the recent MMC-HVDC work [6] to identify opportunities for improvement.
2. Modeling of the MMC–PV System
    - Develop or refine an existing MATLAB/Simulink model of the MMC-PV system
    - Implement models for internal dynamics: currents and voltages
    - Define performance metrics and control objectives.
3. Controller Design
    - Select an appropriate MIMO control method (state-feedback, LQR, MPC, etc.).
    - Design a centralized controller to regulate both internal and external loops.
    - Ensure stability, robustness, and voltage balancing capabilities.
4. Simulation and Validation
    - Integrate the MIMO controller into the MMC–PV model.
    - Evaluate performance under different scenarios (irradiance fluctuations, load variations, grid disturbances).
    - Compare results with the classical PI-based control approach.

IV. Required Skills

The candidate should have a solid background in automatic control and power electronics. Proficiency in MATLAB/Simulink for modeling and controller design is required. The work can be conducted in English or French, depending on the candidate's language skills.

This research is carried out in the framework of the International Associated Laboratory between UGE and Politecnico di Milano. The internship is expected to be continued through a double diploma Ph.D. thesis.

V. Internship Information

Duration: 5 to 6 months, with a planned start date between February 1 and March 31, 2026.
Location: Université Gustave Eiffel, Campus Marne-la-Vallée, bâtiment Bienvenüe, 5 Boulevard Descartes, Champs-sur-Marne F-77454 Marne-la-Vallée Cedex 2, France
How to Apply: Please send your CV, most recent transcripts, and motivation letter to: asma.achnib@univ-eiffel.fr, gilney.damm@univ-eiffel.fr
Application Deadline: **January 5, 2026**

VI. References

[1] Raimi, D., et al. (2024). *Global energy outlook 2024: Peaks or plateaus*. Resources for the Future.
[2] Calvin, K., et al. (2023). *IPCC, Climate Change 2023: Synthesis Report*. IPCC, Geneva.
[3] Teodorescu, R., Liserre, M., & Rodriguez, P. (2011). *Grid converters for photovoltaic and wind power systems*. John Wiley & Sons.
[4] Debnath, S., et al. (2014). Operation, control, and applications of the modular multilevel converter: A review. *IEEE Trans. Power Electronics*, 30(1), 37–53.
[5] Barresi, M. (2022). *Multilevel power converters to integrate renewables and storages into electrical grids*.
[6] Lourenco, L. F. N., et al. (2024). Nonlinear Controller for MMC-HVdc Operating in Grid-Forming Mode. *IEEE Trans. Control Systems Technology*.