

Research internship proposal - Master (M2), Academic year 2024-2025

Nonlinear control of electric vehicles charging to cope with power systems inertia reduction and frequency instability

Internship Supervisors

[Gilney DAMM](mailto:gilney.damm@univ-eiffel.fr), COSYS/IMSE – Université Gustave Eiffel gilney.damm@univ-eiffel.fr

[Mariana NETTO](mailto:mariana.netto@univ-eiffel.fr), COSYS/PICS-L – Université Gustave Eiffel mariana.netto@univ-eiffel.fr

Context

The electrical power system is changing very fast because of the arrival of renewable energy sources (renewables), mostly in the form of distributed generation, and Electric Vehicles (EVs). The main characteristics of either are that they are based on power converters, so include a Direct Current (DC) link, to interface them with the legacy utility grid in Alternative Current (AC). In addition, most storage systems like batteries, and fuel cells are in DC, while modern loads like computers, tablets, and cell phones are also in DC. This will lead in the long run to SmartGrids and MicroGrids partially in DC.

An important point in this current trend is that this increase in DC elements (or even DC MicroGrids), will continuously reduce the amount of inertia, ultimately leading to AC grids only composed of power electronics, and as a consequence, inertia-less. One of the most important challenges for systems with small amounts of inertia like islanded MicroGrids is that they are more sensitive to system disturbances due to less stored energy to compensate for energy imbalances and to slow the rate of change in frequency. As a consequence, even mild disturbances may cause the power system frequency to fall very quickly and there is a high likelihood of a power system blackout [1,2]. This has already started, with lack of inertia being the main reason for some blackouts [3,4].

From the theoretical point of view, this problem is seen as an interconnection of nonlinear systems, with time-varying external parameters and network topologies, with only local measurements available for control. In addition, such systems present different time-scales, with unknown equilibrium points. All these features make their stabilization challenging, even though they represent critical infrastructures. Current strategies are to oversize the system and to add large amounts of storage. But following the speed the grid is changing, neither are economically sustainable nor feasible in due time. For this reason, it is capital to develop new control strategies based on the existing system (with as small as possible new elements) to allow a smooth change in the following years.

Objectives of the internship project

The proposed work aims to investigate how to use power inverters, and in particular, large EVs charging stations and DC MicroGrids to provide inertia emulation and help stabilize the reduced inertia AC grid. This is expected to be attained through new intelligent control algorithms (nonlinear, adaptive, predictive) in a distributed manner, mostly based on local measurements. This is a strategic topic for future grids and will allow their development to mitigate the effect of future increases in DC elements such as renewables, electric vehicles, and storage systems like batteries and supercapacitors. Furthermore, this inertia emulation is even more efficient and cost-effective if using small power reserves. For this reason, electric vehicle charging stations are a very interesting way of providing this power reserve. Bi-directional charging stations can provide the necessary reserve, such as to create MicroGrids that provide the lacking inertia to the main grid [5].

The proposed internship will investigate how to obtain inertia emulation and frequency support from several interconnected sources (PVs, wind turbines) and storages (charging stations, stationary batteries) to the main grid through power converters [10].

The main objectives around the theme of the proposed internship are:

- Understand the interconnected non-linear dynamics of the power system, particularly frequency and inertia, and how to stabilize the system
- Synthetic inertia emulation and frequency control for charging stations and MicroGrids
- Analysis of the stability (especially by Lyapunov theory) of electrical networks integrating a large share of electric vehicles and renewable energies

Method

The starting point will be a series of results from the team, bridging the fields of nonlinear control and power systems/power electronics such as [6-10]. The work of the internship will follow different steps:

- Carry out a literature review on the subject
- Study the results of the supervising team. To do this, study/revise if necessary with the supervisors certain key control techniques (non-linear, adaptive, etc.)
- Study the problems defined above and simulate on Simscape the proposed algorithms

Background

We look for strongly motivated candidates with a background in either control (nonlinear control) or mathematics (dynamical systems, nonlinear systems). Knowledge in the complementary field (electric engineering, power electronics) will be appreciated. Previous experience in simulation environments Matlab/Simulink/Simscape will be acknowledged.

Internship information

Duration: up to 6 months (spring/summer 2025)

Address:

Université Gustave Eiffel

Marne-la-Vallée Campus

5 Boulevard Descartes • Champs-sur-Marne

F-77454 Marne-la-Vallée Cedex 2 • France

Application: Please send an email with your most recent transcripts, CV and motivation letter to mariana.netto@univ-eiffel.fr and gilney.damm@univ-eiffel.fr.

References

- [1] ENTSO-E Position Paper Stability Management in Power Electronics Dominated Systems: A Prerequisite to the Success of the Energy Transition June 2022
- [2] "Stability management in power electronics dominated systems: A prerequisite to the success of the energy transition," ENTSO-E, Tech. Rep., 2022. [Online]. Available: <https://www.entsoe.eu/news/2022/06/21/entso-e-publishes-a-positionpaper-on-stability-management-in-power-electronics-dominatedsystems/>
- [3] "Preliminary report: black system event in south australia on 28 september 2016," Australian Energy Market Operator, Tech. Rep., 2016.
- [4] "9 august 2019 power outage report," OFGEM, Tech. Rep., 2019.
- [5] N. B. Arias, S. Hashemi, P. B. Andersen, C. Træholt, R. Romero, Distribution system services provided by electric vehicles: Recent status, challenges, and future prospects, *IEEE Transactions on Intelligent Transportation Systems* (2019) 4277–4296.
- [6] V. Cuong Nguyen, M. Netto, G. Damm. Control of a DFIG based wind turbine using modified Conditional Servo-compensator. *IFAC-PapersOnLine*, Volume 56, Issue 2, 2023, Pages 7668-7673, ISSN 2405-8963, <https://doi.org/10.1016/j.ifacol.2023.10.1167>.
- [7] S. B. Siad, A. Iovine, G. Damm, L. Galai-Dol, M. Netto. Nonlinear Hierarchical Easy-to-Implement Control for DC MicroGrids. *Energies* 2022, 15(3), 969.
- [8] L. F. Normandia Lourenço, A. Louni, G. Damm, M. Netto, M. Drissi-Habti, S. Grillo, A. J. Sgarezi Filho, L. Meegahapola. A Review on Multi-Terminal High Voltage Direct Current Networks for Wind Power Integration, *Energies* 2022, 15(23), 9016.
- [9] Erico Gurski, Roman Kuiava, Filipe Perez, Raphael A. S. Benedito, Gilney Damm, "A Novel VSG with Adaptive Virtual Inertia and Adaptive Damping Coefficient to Improve Transient Frequency Response of MicroGrids", *Energies*, to appear.
- [10] Filipe Perez, Gilney Damm, Cristiano Maria Verrelli, Paulo Ribeiro, "Adaptive Virtual Inertia Control for Stable Microgrid Operation including Ancillary Services Support", *IEEE Transactions on Control Systems Technology*, doi: 10.1109/TCST.2023.3234282, vol. 31, no. 4, pp. 1552-1564, July, 2023.