M2 internship proposal

Experimental and numerical implementation of converter controls dedicated to Smart Grid emulation

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Background

Electricity grids are undergoing radical change. The widespread use of variable renewable energy production and the increasing use of flexible consumption are raising a host of issues. Some of these are linked to the growing presence of power electronics connected to the networks, such as the static converters that inject wind and photovoltaic energy. By way of example, the European H2020 Migrate[1] project has mobilised €17M, researchers and industry for 4 years on the associated issues.

Control laws for network converters are an open scientific problem in which many different architectures have been proposed. Among the grid forming or grid feeding approaches, validations are often only numerical, on microgrid models considering only disturbances around an operating point without considering start-up. In addition, the simulations are based on modelling assumptions that do not represent the reality of problems such as Electro-Magnetic Compatibility (EMC) interference, the appearance of harmonics or instabilities such as the circulation of common-mode currents[3, 4].

Another difficulty lies in representing the complexity of the electrical network : a large number of agents interact with each other, and the number of architectural, parameter and control degrees of freedom is very large. To analyse exhaustively the effect of a static converter controller on a network when the network parameters themselves have an influence on the converter is a delicate task ; a universal converter control algorithm that works for all networks under all conditions remains a utopia today.

FIGURE 1 – Electrical cabinet with 10 opENS inverters.

In this context, the SATIE and IETR laboratories at ENS Rennes are proposing the opENS platform [5]. It consists of a set of autonomous network agents that communicate with each other and exchange power using an integrated static converter. These agents form an instrumented experimental platform for the Smart Grid, whose originality lies in the fact that it enables ambitious tests to be carried out without the risk of costly breakdowns or jeopardising the continuity of service of real power grids. This platform is adapted to the experimental validation of algorithms for controlling static converters in networks. It is now operational and the first experiments have been carried out. However, the control laws can be improved and certain instabilities appear when using a large number of agents.

Proposed work

The proposed work breaks down into several stages :

- A bibliographical study must first be carried out in order to familiarise ourselves with the control algorithms for grid-connected inverters, with a critical eye on the experimental aspects and the control of instabilities.
- Training in the use of the opENS experimental platform.
- Defin a simple scenario with 2 or 3 agents to reproduce an instability. Program the on-board computers in Python and the inverter DSPs in C to implement these scenarios experimentally.
- Produce a digital twin simulation reproducing the phenomena observed.
- Choose a few algorithms from the state of the art, then implement them on the opENS experimental platform as well as on the digital twin. Particular attention will be paid to the measurements so that the results can be used for futur publication.
- Analyse the results to propose an explanation for the instabilities, characterise the area in which they occur, and propose remedies.
- Write the brief and associated presentation.

Depending on the quality of the trainee and the funding granted, the student may go on to complete a thesis.

Skills required

The candidate must have previous knowledge of electrical engineering : power electronics, control, converter simulation. Mastery of a scientific computing language (Python, Julia, Matlab, etc.), electrical simulation software (Spice, Simulink, PSIM, PLECS, or other, etc.) and basic knowledge of C are expected. In addition, an interest in energy transition issues and the operational development of renewable energies is a plus.

In addition to their scientific skills, trainees must be curious and able to work independently on a variety of tasks ranging from theory to practice, including simulation and writing.

Organisation

The internship will take place in the IETR laboratory at ENS Rennes, Ker Lann campus. It will last 6 months. It will be paid at the legal minimum rate.

The trainee will work in the SyEnsCES team : Systèmes Energétiques et transduCteurs Electriques Soutenables, which consists of 4 permanent staff and around ten PhD students and postdocs. This team is part of the Mechatronics department at ENS Rennes, with around twenty permanent staff and more than twenty PhD students and trainees.

Références

[1] H2020 MIGRATE project, https://www.h2020-migrate.eu/

[2] DENIS, Guillaume. Les nouvelles stratégies de contrôle d'onduleurs pour un système électrique 100% interfacé par électronique de puissance. 2017. Thèse de doctorat. Ecole centrale de Lille. https://tel.archives-ouvertes.fr/tel-01905827

[3] Zhang, L., Sun, K., Xing, Y., & Zhao, J. (2015). Parallel operation of modular single-phase transformerless grid-tied PV inverters with common DC bus and AC bus. IEEE Journal of Emerging and Selected Topics in Power Electronics, 3(4), 858-869.

[4] Wang, X., Zou, J., Peng, Y., Xie, C., Li, K., & Guerrero Zapata, J. M. (2018). Elimination of zero sequence circulating currents in paralleled three-level T-type inverters with a model predictive control strategy. IET Power Electronics, 11(15), 2573-2581.

[5] JODIN, Gurvan, HERAULT, Guillaume, LE GOFF-LATIMIER, Roman, HLIOUI, Sami, ROSTAING, Gilles et BEN AHMED, Hamid. opENS : un concept de prototype de Smart Grid à puissance réduite, faible coût, libre et ouvert. Symposium de Génie Electrique SGE 2020. https://hal.archives-ouvertes.fr/hal-03099423/