MASTER2 PROJECT PROPOSAL:

Comparative assessment of inverter control strategies in a community AC microgrid context

Contacts: **Antoneta Iuliana BRATCU**: antoneta.bratcu@gipsa-lab.grenoble-inp.fr, +33-476 826 384

Keywords:
Inverter-based microgrid, inverter control, grid-forming inverter, grid-following inverter, droop control, robust $\mathcal{H}_\infty$ control

DESCRIPTION AND OBJECTIVES:

In a landscape dominated by conventional power grids employing synchronous generators in charge with ensuring the grid secure operation by providing ancillary services such as voltage and frequency regulation, the inverter-based microgrids are increasingly necessary to accommodate the distributed energy resources (DERs). Most of DERs are equipped with ***grid-following*** inverters (GFLIs). Unlike the synchronous generators, GFLIs are not intrinsically characterized by inertial responses, therefore this transition raises technical challenges for the grid's stability. A possible solution is adoption of ***grid-forming*** inverters (GFMIs) which can emulate the characteristics of synchronous generators if appropriately equipped with improved damping and virtual inertia1 [1]. Moreover, use of GFMIs combined with intelligent load shedding can ***enhance grid reliability and resilience*** by enabling the provision of energy to critical facilities during power outages [2].

This internship is focused on providing pertinent control solutions in the larger context of community microgrids. A ***community microgrid*** includes several GFMIs and is designed to serve the energy needs of a residential neighbourhood, a building complex, *etc.*, in both *grid-connected* and *standalone* operating modes. Community microgrids can be owned and operated by local communities in a decentralized manner, rather than by a centralized utility. A community microgrid may be defined as a *cluster of neighbouring microgrids* connected via interlinking converters, improving the reliability and economic performance of individual microgrids [3]. In this context, an individual microgrid might cooperate with neighbouring microgrids for back-up operations in emergencies and for economic purposes.

Starting from studying the dynamic behaviour and control of a single GFMI, then continuing with a simple, yet representative microgrid topology – at least two GFMIs in interaction – the decentralized control of GFMIs equipped with improved damping and virtual inertia is aimed at. Based on devising suitable control-oriented mathematical models, a first step will be to identify which control strategies for GFMIs within a community microgrid are most effective in *grid-connected*, as well as in *standalone* modes. Ensuring a *smooth switching* between the two modes is also required. In a second step, closed-loop preliminary validations by numerical simulation will provide a basis towards experimental validation of a community microgrid on a laboratory scale.

Our study will in a first time concern the ***dynamic behaviour analysis and control of a single GFMI*** connected to a distribution grid. A comprehensive review, classification and critical comparison of several control strategies for GFMIs in a simulation case study can be found in [4], where four major categories of GFMI have been identified: a) droop control; b) virtual synchronous machine; c) matching approach; and 4) virtual oscillator-based control. The key challenges were summarized to be further investigated prior to large-scale integration of GFMIs into low-inertia grid infrastructure.

Taking into account operation of a single GFMI in a community microgrid context, control strategies must already envisage embedding a maximum of its microgrid operation constraints, that is, a decentralized control vision should be adopted from the very beginning. Use of ***droop control*** in both grid-connected and standalone operating modes can reasonably be taken as a baseline; other strategies should be further assessed against this latter. Not at least, the ***fault ride-through*** requirements of a community microgrid, considering load imbalances and short circuits, should also be taken into account in the control design. In order to satisfy the requirements set by relevant ***grid codes*** (*e.g.*, SR 734.27 in Switzerland [5]), ***robustness*** and ***optimality*** of the proposed control strategy must be addressed. With this respect, the formalism of ***$\mathcal{H}_\infty$-based robust control*** design can provide a pertinent framework leading to very well-performing closed-loop behaviour [6]–[8].

MASTER THESIS OBJECTIVES:

- bibliographical search focused on identifying the most pertinent state-of-the-art control-oriented modelling and control methods of inverters in a community microgrid context
- PLECS – MATLAB®/Simulink® simulation of models and control strategies of a single inverter in both grid-following (grid-connected) and grid-forming (standalone) microgrid cases, yielding a critical assessment of performances in terms of advantages and drawbacks of each control strategy
- simulation analysis of smooth switching between the two connection cases
- study of implementation constraints on hardware microgrid topologies available at the Institut des Energies at Yverdon-les-Bains in Switzerland
- concluding on which control approaches are most effective in *grid-connected* and *standalone* operational modes with a community microgrid context

SUPERVISING:

This internship will be jointly supervised by Dr. Antoneta Iuliana BRATCU, Associate Professor HDR with Grenoble Image Parole Signal Automatique (GIPSA-lab) at University Grenoble Alpes and Grenoble Institute of Technology and Management, and Professor Mauro CARPITA and Associate Professor Mokhtar BOZORG, both with University of Applied Sciences Western Switzerland (HES-SO) and Institute of Energies, Yverdon-les-Bains, Switzerland, as a part of a collaboration between the two research units, in France and Switzerland, respectively.

References

[1] Z. Li, M. Shahidehpour, F. Aminifar, A. Alabdulwahab and Y. Al-Turki, "Networked microgrids for enhancing the power system resilience," *Proceedings of the IEEE,* vol. 105, no. 7, pp. 1289-1310, 2017.

[2] B. Chen, J. Wang, X. Lu, C. Chen and S. Zhao, "Networked microgrids for grid resilience, robustness, and efficiency: A review," *IEEE Transactions on Smart Grid,* vol. 12, no. 1, pp. 18-32, 2020.

[3] L. Che, M. Shahidehpour, A. Alabdulwahab and Y. Al-Turki, "Hierarchical coordination of a community microgrid with AC and DC microgrids," *IEEE Transactions on smart grid,* pp. 3042-3051, 2015.

[4] A. Tayyebi, F. Dörfler, F. Kupzog, Z. Miletic and W. Hribernik, "Grid-forming converters–inevitability, control strategies and challenges in future grids application," *CIRED,* 2018.

[5] *734.27 Ordonnance sur les installations électriques à basse tension (OIBT),* Berne: Le Conseil fédéral suisse, 7 novembre 2001.

[6] Q.-L. Lam, A.I. Bratcu, C. Boudinet, M. Thomas, A. Labonne and D. Riu, "Primary frequency H∞ control in stand-alone microgrids with storage units: a robustness analysis confirmed by real-time experiments," *International Journal of Electrical Power and Energy Systems*, 115, art. no. 105507, 2020.

[7] Q.-L. Lam, A.I. Bratcu and D. Riu, "Multi-variable H∞ control approach for voltage ancillary service in autonomous microgrids : design and sensitivity analysis," *IEEE Access*, 9, pp. 140212–140234, 2021.

[8] Q.-L. Lam, D. Riu, A.I. Bratcu, A. Labonne and C. Boudinet, "Power hardware-in-the-loop validation of primary frequency robust control in stand-alone microgrids with storage units," *Electrical Engineering*, 105 (1), pp. 317-333, 2023.

INTERNSHIP ORGANIZATION:

6 months internship (from February to July 2024) financially supported (about 600 Euros net per month) by the MODUS (Modelling and Optimal Decision for Uncertain Systems) Research Team from Control Systems and Diagnostics Division at GIPSA-lab, with the possibility of passing several weeks at the Institut des Energies, Haute école d'Ingénierie et de Gestion du Canton de Vaud, Yverdon-les-Bains, Switzerland.