Integration of Grid-Forming converters in an unbalanced transmission power system

Research Group

- **L2EP**, Laboratory of Electrical Engineering of Lille, https://l2ep.univ-lille.fr
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Introduction and general context

In the context of massive integration of Renewable Energy Sources (RES) in the global energy mix, the electrical power system requires a deep transformation. At any scale, the production, transmission, distribution and consumption subsystems are modified to consider that RES are fundamentally non-controllable. Among the main technical impacts, more and more devices are connected to the electrical grid with the help of a Power-Electronics (PE) converter, whether in energy production or consumption systems.

In the history of power systems, the use of Power-Electronics to make more flexible the power control at the interface with the electrical grid is a few decades old. Until now, it has been done under the assumption that the fundamental 50Hz or 60Hz sinus shape of electrical voltage remains driven by rotating synchronous machines, in a reduced number of big electricity production plants evenly distributed across a territory. In this condition, any device connected to the grid "follows" the synchronous machines voltage waveform. PE converters are no exception to this principle, so they lie on an internal control called "Grid-Following (GFL) control", where the current is controlled in synchronization with grid's robust sinus voltage. In recent years, this mode of operation has been gradually called into question, because the dominant production system lying on synchronous machines is being progressively replaced by smaller but more numerous RES production units. There, the question arises of who controls the sinus voltage waveform?

"Grid-Forming" control theory of PE converters comes from this need, to move voltage control from usual synchronous machine power plants to a sum of lower power-sized devices connected to the power system.

L2EP is a French research laboratory specialized in the fields of electrical engineering and power-electronics. Among its main activities, the L2EP power system team works on PE converters integration into the electrical grid, focusing on control design, stability analysis, and experimental validations. During the last decade, in collaboration with industrial partners such as the French Transmission System Operator (TSO) RTE, L2EP lab. has developed an expertise about grid forming control [01]. Many experimentations, at transmission and

distribution levels have been achieved, validating grid-forming control theory, proving the robustness of the control under a set of functional scenarii. For the power system operators such as RTE, these studies are interesting to understand the opportunities as well as the limitations of grid-forming controlled converters, such as defining the future grid-codes. If today we understand quite well how to operate grid-forming in the situation of balanced 3-phase systems, we need to enlarge the scope to unbalanced situations. This Ph.D. project is proposed to cover this objective.

Ph.D. objectives

In the perspective of defining the future grid-codes of the transmission power system in unbalanced conditions, the Ph.D. objectives are to contribute to the analysis of the opportunities and limitations, as well as the development of control methods (especially grid-forming control), of PE converters operating in such conditions. The Ph.D. student will have to drive a scientific work to answer the following questions:

- Functional specification: What should be the behavior of Power-Electronics control in case of an unbalanced system? Should it control a balanced system of voltages or a balanced system of currents? Should it be a compromise between both? Here, the first main question is focused on connection / disconnection of unbalanced loads, studying both the transient and the permanent phases. In a second step, the behavior of PE converter in case of unbalanced faults on the power system may be also investigated.

- Architecture specification: What are the required converter connection schemes, compliant with the balancing control objectives (with focus on grounding and transformer coupling).

- How to update Grid-Forming control in unbalanced conditions?

- What kind of analysis method and tools can be used?

Experimentations, based on L2EP facilities will be done to verify theoretical concepts.

Position Requirements

As an ideal PhD candidate:

- You have a MSc with a relevant background in electric power systems or power electronic converters with application in power systems, preferably from a reputable institute from a country within the European Economic Area.
- You should have obtained excellent study results.
- You should have a keen interest to work in a team with experts studying different aspects of power electronics and power systems.
- You have experience with one or more of the following: power system dynamics, control design, power electronic converters, electrical networks

- You have excellent written and oral communication skills in English.

Localization and supervision

L2EP is a Laboratory of Electrical Engineering and Power electronic, located at Lille – France (https://l2ep.univ-lille.fr/). The Power Systems group at L2EP began working on the integration of power electronic converters into the AC grid 15 years ago. Since then, numerous PhD theses have been completed on this topic, supported by European projects and direct collaborations with major grid stakeholders such as RTE, EDF, and ENEDIS. For the past four years, the group has also been organizing a highly successful summer school focused on grid-forming control. (https://centralelille.fr/summer-school-power-electronic-on-power-system/)

RTE it the French transmission system operator, its R&D have more than 130 employees with multiple PhD students. It has been involved in GFM research for more than a decade, from research through different EU project (such as MIGRATE, OSMOSE …) and various collaborations with universities to its practical implementation in grid code.. Its employees are working on a wide variety of subject such as system stability, optimization , generation / load forecast, simulation tools…
https://www.rte-france.com/en/home

Ph.D. main location will be L2EP laboratory, integrated within a team of around 10 Ph.D. or post-doc, or internship students, under the co-supervision of L2EP and RTE staff members.

How to apply?

Send the following elements by email to: phd.position@epmlab.eu

- CV
- Cover letter
- Reference letters. At least one reference letter from your Master internship supervisor is necessary.
- Grades obtained during the master, and ranks.

Selected candidates will be evaluated on technical skills and on their research capabilities (e.g. reviewing a paper or testing and analyzing a simulation)