Development of New Methods for Stability Assessment of Power Grids with High Integration of Renewable Energy Sources (GRID-STab)

PhD Description

PhD thesis under joint supervision between Centrale Lille Institute and the Polytechnic School of Tunisia

Research Groups

- L2EP : Laboratoire d'électrotechnique et d'électronique de puissance, Lille – France (https://l2ep.niv-lille.fr)
- LIM : Laboratoire d'Ingénierie Mathématique à l'Ecole Polytechnique de Tunisie (EPT), La Marsa, Tunisie (http://www.ept.rnu.tn/).

Supervisors

- Pr. GUILLAUD Xavier (L2EP)
- Pr. JAMMAZI Chaker (LIM)
- Dr. BELHAOUANE Moez (L2EP)

Introduction and General Context

The European Commission has launched the Green Deal, an ambitious initiative aimed at accelerating the energy transition and achieving carbon neutrality by 2050. Among the key objectives of the Green Deal are specific targets for 2030, including the integration of 40% renewable energy in the European energy mix and increasing the share of electricity to 30% of final energy consumption. This latter objective will be largely supported by the increased electrification of various sectors such as transport, heating, and industry, to reduce dependence on fossil fuels and promote a more sustainable and resilient energy system.

Thus, grid operators must anticipate the energy transition characterized by a high integration of renewable energy sources (RES), particularly wind and solar, connected to both transmission and distribution networks. Since these renewable sources are intermittent, they also require the use of energy storage solutions. Furthermore, RES and their associated storage systems are integrated into the grid via power electronic converters, leading to a significant increase in inverter-based resources (IBRs). As shown in Figure 1, this shift is likely to alter the dynamics of the power system, as IBRs behave differently from conventional generation units based on rotating machines.

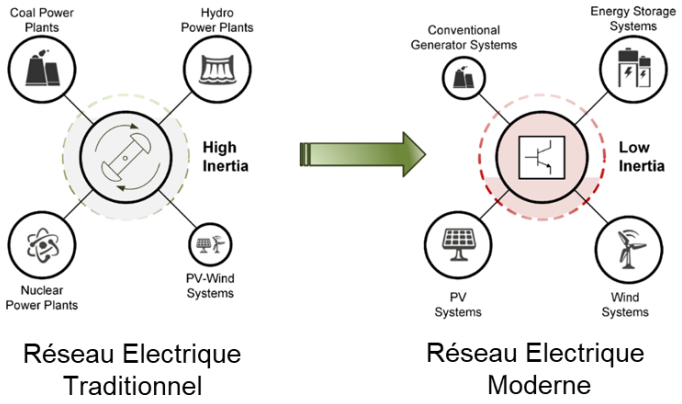

Figure 1 : *Power system evolution*

As a result, power system operators must implement intelligent and adaptive analysis and control solutions to effectively address these new requirements. In a context where power electronic devices play an increasingly prominent role in electrical networks, it is essential to ensure safe and reliable energy transmission and distribution while addressing the emerging stability challenges of modern grids, which that even call for an expanded definition of the concept of stability [1]. To this end, the development of advanced methods for assessing power system stability has become essential, not only to identify instability risks but also to anticipate them under a wide range of operating conditions [2].

Scientific Challenges

- Limitations of traditional analyses based on linearized models and eigenvalue assessments of the controlled power system.
- Lack of formal criteria and precise indicators to assess the overall stability of the system.
- Optimal placement and sizing of Grid-Forming (GFM) converters to expand the stability domain.
- Integration of black-box models into the small-signal stability analysis of power systems.
- Impact of the operating point on system stability and assessment of global stability along the electrical system trajectory.

PhD Objectives

The proposed PhD topic builds on the ongoing research conducted by the Power Systems Team at L2EP on the stability of electrical grids with a high share of power electronics, and in particular the recent work of Mr. Lamrani [3]. The objectives of the PhD are structured around the following key areas:

- **Deepening small-signal stability analysis:** Development of precise criteria and advanced indicators to anticipate instabilities and optimize the placement of Grid-Forming (GFM) converters.
- Stability analysis integrating black-box models.

- **Stability analysis across multiple operating points:** Design of advanced strategies to assess system stability along its dynamic trajectory.

Thesis Progression and Location

This three-year PhD thesis is carried out under a joint supervision agreement between the L2EP laboratory (Lille, France) and the LIM laboratory at the Polytechnic School of Tunisia.

The doctoral candidate will spend the first part of the thesis (18 months) at L2EP in France, followed by the second part (also 18 months) at LIM in Tunisia.

Requirements

- Hold an engineering degree (Level 7) or a master's degree (MSc) with a specialization in electrical power systems or power electronics applied to electrical grids.
- Demonstrated an excellent academic performance.
- Strong interest in the teamwork
- Strong knowledge in one or more of the following areas: power system dynamics, control design, power electronic converters, electrical grids and stability of complex dynamic systems.
- Excellent written and oral communication skills in both French and English.

How to Apply ?

To apply for this PhD position, please send the following documents by email to the following address: phd.position@epmlab.eu

- CV
- Cover letter
- Reference letters (at least one from your Master's internship supervisor, or another academic or professional referee)
- Grades obtained from the last two academic years and ranks.

Shortlisted candidates will be evaluated based on their technical skills as well as their research potential. For any further information, please do not hesitate to contact: Xavier GUILLAUD (xavier.guillaud@centralelille.fr) and Moez BELHAOUANE (moez.belhaouane@univ-lille.fr).

Bibliographic References

[1] N. Hatziargyriou, J. Milanovic, C. Rahmann, V. Ajjarapu, C. Canizares, I. Erlich, D. Hill, I. Hiskens, I. Kamwa, B. Pal, P. Pourbeik, J. Sanchez-Gasca, A. Stankovic, T. Van Cutsem, V. Vittal, and C. Vournas, "Definition and Classification of Power System Stability – Revisited & Extended," IEEE Transactions on Power Systems, vol. 36, no. 4, pp. 3271–3281, Jul. 2021.

[2] C. Cardozo, T. Prevost, S.-H. Huang, J. Lu, N. Modi, M. Hishida, X. Li, A. Abdalrahman, P. Samuelsson, T. V. Cutsem, Y. Laba, Y. Lamrani, F. Colas, and X. Guillaud, "Promises and Challenges of Grid Forming: Transmission System Operator, Manufacturer and Academic Viewpoints," 2024.

[3] Y. Lamrani, “Localisation optimale des convertisseurs grid forming sur les réseaux de transport pour l'amélioration de la stabilité petits signaux,” Centrale Lille Institute, 2024.