Grid-Forming IBRs for enhancing stability in sustainable power systems

Project information

Name: GFMBEING. Grid-ForMing Inverter Based Resources for enhancing stability in sustainable power systems: BEyond the INertial response

Project ID: PID2024-157833OB-I00

Funding organization: Ministry of Science, Innovation and Universities

Position: Funded PhD student

Principal investigators: Prof. Jose Maria Maza-Ortega
Assoc. Prof. Francisco de Paula García López

Starting date: May 2026

Contract duration: 4 years

Location: Department of Electrical Engineering
Escuela Técnica Superior de Ingeniería
Camino de los Descubrimientos s/n
41092 Seville (Spain)

Salary: First year: 31 k€ + 7 k€ (stays in research centers). Second and third year: 31 k€. Four year: 31 k€ + 3.2 k€ (end of contract).

Requirements

Degree: A Master degree (or equivalent) in Electrical Engineering, Energy Systems, Power Electronics, or a related field.

Experience: modelling and simulation tools (e.g., Python, MATLAB, TyphoonSim), electromechanical and electromagnetic simulation, Hardware in the Loop (HIL) testing technologies, experimental validation of power electronics prototypes.

Language: Proficiency in English (written and spoken). Knowledge of Spanish is valuable but not essential.

Other technical skills: Strong knowledge of power systems, renewable energy integration in transmission/distribution networks, grid-forming converters.

Other soft skills: communication, teamwork, interpersonal skills and critical thinking.

Project summary

GFM-BEING addresses the impact of Grid-Forming Inverter Based Resources (GFM-IBR) in decarbonized electric power and energy systems (EPES). The on-going replacement of traditional synchronous generation assets by renewable energies interfaced with power electronics is leading the EPES to a new situation characterized by a volatile generation mix, a lower inertia, a lower stiffness and with electromechanical and new converter-driven oscillatory phenomena. Therefore, and considering the constrained investments on the transmission and distribution levels, the security of supply and stability of the EPES will be compromised in the near future.

In this context, GFM controllers have emerged as a cornerstone of the converter-dominated EPES with new capabilities with respect to the conventional Grid Following (GFL) technology. GFM IBRs are operated as a voltage sources, which are power synchronized with the voltage grid, mimicking to some extent the performance of synchronous generators. This feature unlocks the possibility of providing ancillary services like inertial response or black start, which are not possible in the case of GFL IBRs. However, GFM IBRs still differ from synchronous generators as their short-circuit current capability is low due to the inherent characteristics of power electronics.

GFM-BEING is moving a step forward to analyze the contribution of the GFM IBRs beyond the classical ancillary services, exploring the damping of electromechanical and converter-driven oscillations, the enhancement of transient stability during large-disturbances and the seamless transitions from grid-connected to islanded operation modes and vice versa. Moreover, new design IBR procedures devoted to increase the overloading capability of IBRs during short-circuit faults will be explored.

With these objectives in mind, GFM-BEING is a comprehensive proposal addressing device- and EPES-oriented challenges which will contribute to the security of supply and stability of sustainable EPES. On the one hand, GFM controllers will be designed considering simplified yet representative EPES dynamic models. Moreover, it is intended to define a unified GFM controller with a set of ancillary services that can be tailored to transmission/distribution applications. On the other hand, GFM-BEING will analyze, through key performance indicators, the impact that different GFM technologies will have in benchmark transmission and distribution networks, particularly how this technology with extended short-circuit capability may contribute to maintain the legacy protection system. In the case of transmission networks, the damping of oscillatory phenomena and improvement of transient stability during short-circuit faults will be also studied. Moreover, and in the case of distribution networks, the focus will pivot on the improvement of the continuity of supply to the final users resorting to islanded operation provided by GFM IBRs in tandem with battery energy storage systems.

All the concepts proposed in GFM-BEING will be experimentally tested in the laboratory to reach the highest possible Technology Readiness Level (TRL). With this regard and considering the followed device- and system-oriented approach, GFM-BEING envisions: (i) unitary tests of GFM IBRs to validate their individual performance, but also (ii) integrated testing of GFM IBRs within the cyber-physical EPES laboratory of the Department of Electrical Engineering at the University of Sevilla.

Planned training activities

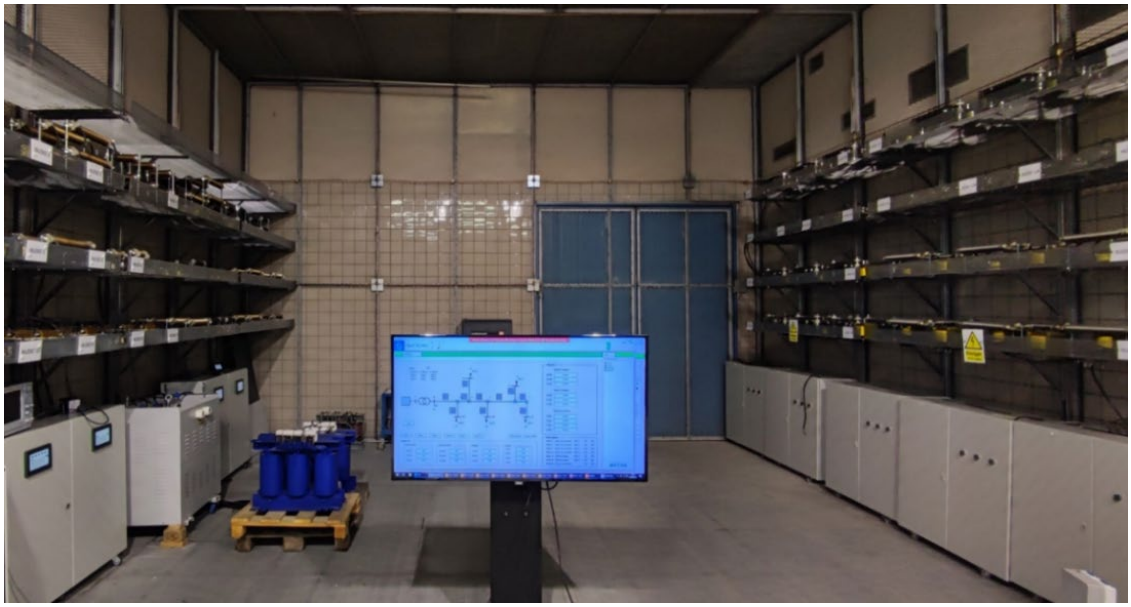
The candidate will be incorporated in the research group Electric Power Systems (TEP-196 in the Andalusian Plan of Research, Development and Innovation - PAIDI) led by Prof. Antonio Gómez-Expósito and composed by 25 PhD engineers (8 professors,12 associate professors and 5 assistant professors). The research group has relevant experience in training with a special focus on doing applied research to solve real EPES problems, taking advantage of the good connections with the industry.

The predoctoral candidate will enroll in the Joint PhD Program on Electric Power Systems (https://institucional.us.es/doctoradosee/), coordinated by the University of Sevilla and shared with University of Málaga, University of Basque Country and University Polytechnic of Catalunya. As a doctoral student, the candidate will enjoy a training program designed to foster both technical and soft skills, organized by the Academic Committee of the PhD Program and the International School of Doctorate, respectively (https://institucional.us.es/doctoradosee/informacion-academica/actividades-formativas/). In addition, the PhD Program is aware of additional dissemination activities organized by research institutions which contribute to the training of students, such as those organized by *DERLab* and *IEEE PES Spain Chapter,* which are announced in the internet forum *PowerGlobe*. Furthermore, the PhD Program encourages the students to widen the research relationships beyond their corresponding supervisors. Internal PhD students workshops and other national special events organized by the *IEEE PES Spain Chapter* are promoted. In this line, the PhD also animates students to program predoctoral stays in prestigious foreign research centers taking advantage of the international character of the program. Particularly, the research group has excellent relationships with the following universities: University of Colorado Denver (USA), University of Wisconsin (USA), TU Delft (The Netherlands), Ecole Polytechnic de Lausanne (Swiss), National Technical University of Athens (Greece), University of Thessaloniki (Greece), University of Cyprus, University of Lille (France) and University of Belgrade (Serbia), among others.

Available research facilities

Cyber-Physical Power Systems Laboratory (CPPS Lab). The aim of this laboratory is to validate new control and operation strategies for the electricity system with 100% renewable energy and in which new network assets such as electric vehicles and energy storage systems coexist. To this end, the laboratory has various devices, both in terms of power and digitalisation, that replicate the operating conditions of the current and future electrical system. Specifically, this laboratory consists of the following elements, as shown in the figure below:

- Physical-scale networks that emulate the behaviour of medium and low voltage (MV and LV) electrical networks.
- Power electronics converters (100 kVA, 20 kVA, 14 units) and topology (three-wire and four-wire) that are the main interface with the electrical network for renewable sources, electric vehicles and energy storage systems.
- Power amplifier to feed the networks and power converters (Regatron 50 kVA).
- Energy storage systems such as batteries and supercapacitors.
- Measurement and monitoring equipment distributed throughout the scale networks and power converters.
- Industrial SCADA system that centrally manages and operates the scale networks and converters.
- Advanced Distribution Management System (ADMS) for optimal operation of large-scale networks, including a state estimator and voltage control.
- Real-time simulators composed of analogue and digital signals and communication protocols that enable real-time simulations of power and digital systems.
- Hardware-in-the-loop (HIL) laboratory including OPAL-RT (1 unit), Typhoon HIL 404 (2 units), 406 (1 unit) and 101 (6 units).
- Flagship HIL Teaching Lab from Typhoon HIL Inc. (https://www.linkedin.com/posts/typhoon-hil-inc_universidad-de-sevilla-is-richer-with-a-flagship-activity-7326246843732901889-mSb1/).



Relevant publications of the group

Grid-forming Converters

- F. J. Matas-Díaz, M. Barragán-Villarejo and J. M. Maza-Ortega, “A Systematic Small-signal Analysis Procedure for Improving Synchronization Stability of Grid-forming Virtual Synchronous Generators,” in *Journal of Modern Power Systems and Clean Energy*, vol. 13, no. 1, pp. 102-114, January 2025, doi: 0.35833/MPCE.2024.000316.
- F. J. Matas-Díaz, M. Barragán-Villarejo, J. M. Maza-Ortega, G. C. Kryonidis, K. -N. Malamaki and C. S. Demoulias, “Active Harmonic Filtering With Selective Overcurrent Limitation for Grid-Forming VSCs: Stability Analysis and Experimental Validation,” in *IEEE Transactions on Industry Applications*, vol. 60, no. 3, pp. 4762-4775, May-June 2024, doi: 10.1109/TIA.2024.3369595
- A. E. Leon and J. M. Mauricio, “Virtual Synchronous Generator Design to Improve Frequency Support of Converter-Interfaced Systems,” in *IEEE Transactions on Energy Conversion*, vol. 39, no. 2, pp. 862-871, June 2024, doi: 10.1109/TEC.2023.3333260.
- A. E. Leon and J. M. Mauricio, "Virtual Synchronous Generator for VSC-HVDC Stations With DC Voltage Control," in *IEEE Transactions on Power Systems*, vol. 38, no. 1, pp. 728-738, Jan. 2023, doi: 10.1109/TPWRS.2022.3164027.
- G. C. Kryonidis, K. D. Malamaki, J.M. Mauricio, C.S. Demoulias, “A new perspective on the synchronverter model”, International Journal of Electrical Power & Energy Systems, Vol. 140, 2022, doi: 10.1016/j.ijepes.2022.108072.
- F. J. Matas-Díaz, M. Barragán-Villarejo, J. C. Olives-Camps, J. M. Mauricio and J. M. Maza-Ortega, “Virtual Conductance Based Cascade Voltage Controller for VSCs in Islanded Operation Mode,” in *Journal of Modern Power Systems and Clean Energy*, vol. 10, no. 6, pp. 1704-1713, November 2022, doi: 10.35833/MPCE.2021.000121.

Experimental testing on laboratory

- A.M. Gross-Muresan, F.J. Matas-Díaz, M. Barragán-Villarejo, J.M. Maza-Ortega, E. Romero-Ramos, “Scaled-down three-phase four-wire low-voltage distribution network for testing smart grid technologies”, Sustainable Energy, Grids and Networks, Vol. 43, 2025, doi: 10.1016/j.segan.2025.101810.
- G.C. Kryonidis *et al.*, “Experimental Validation of a Rule-Based Voltage Regulation Algorithm for MV Grids”, 2023 IEEE Belgrade PowerTech, Belgrade, Serbia, 2023, pp. 1-6, doi: 10.1109/PowerTech55446.2023.10202691.
- M. Barragán-Villarejo, F.d.P. García-López, A. Marano-Marcolini, J.M. Maza-Ortega, “Power System Hardware in the Loop (PSHIL): A Holistic Testing Approach for Smart Grid Technologies”, *Energies* **2020**, *13*, 3858. https://doi.org/10.3390/en13153858
- J. M. Maza-Ortega *et al.*, “A Multi-Platform Lab for Teaching and Research in Active Distribution Networks,” IEEE Transactions on Power Systems, vol. 32, no. 6, pp. 4861-4870, Nov. 2017, doi: 10.1109/TPWRS.2017.2681182.