GRID-FORMING POWER CONVERTERS

Implementation, Applications, and Hands-On

COURSE DESCRIPTION

Over the last two decades, electricity networks have progressively shifted from systems dominated by synchronous machines to systems increasingly populated by inverter-based resources such as renewable generation, battery storage, HVDC systems, electric vehicles, and power-electronic loads. In these emerging converter-dominated grids, the dynamic behaviour of the power system is no longer determined primarily by electromechanical machines but by the control strategies embedded in power converters.

Grid-forming (GFM) converters have therefore emerged as a key technological approach to ensure stable and resilient operation of future renewable power systems. By emulating the dynamic behaviour of voltage sources and actively participating in voltage and frequency formation, GFM converters can restore fundamental stabilising mechanisms that are progressively lost as synchronous machines are displaced.

This advanced technical course provides a comprehensive view of grid-forming technology, covering both the control principles of GFM converters and their impact on modern power systems. The course combines theoretical foundations, practical implementation aspects, and system-level applications, addressing topics ranging from synchronization mechanisms and control design to system stability, renewable integration, and microgrid operation. Throughout the three-day program, participants will examine the physical principles underlying grid-forming control and its relation to synchronous power system behaviour, explore practical implementation approaches including the Synchronous Power Controller and other advanced control strategies, and analyse the interaction between grid-following and grid-forming converters in renewable-rich power systems. The course will also discuss the role of grid-forming converters in renewable plants, microgrids, HVDC systems and hybrid AC–DC networks, as well as their impact on power system stability, fault response and grid support services.

In addition to the theoretical sessions, the course includes practical hands-on activities using professional simulation and analysis tools that allow participants to experiment with the modelling, implementation and stability assessment of grid-forming converters in realistic scenarios. The program is intended for PhD students, researchers, and industry engineers working in power electronics, renewable energy systems, and modern power system operation. The instructors are internationally recognised experts and pioneers in the development of grid-forming control technologies. By the end of the course, participants will gain both conceptual understanding and practical skills required to analyse, design and deploy grid-forming converters in future converter-dominated power systems.

TOPICS

Day 1: Fundamentals and Control of Grid-Forming Converters – Prof. Pedro Rodriguez – LIST

- Physical principles of grid-forming converters and synchronization mechanisms in converter-dominated power systems.
- Grid-following, grid-supporting and grid-forming control concepts, including virtual synchronous generation and implementation approaches.
- Practical implementation of grid-forming controls with emphasis on the Synchronous Power Controller and related control strategies.
- Hands-on session: simulation and implementation of grid-forming converters using a PSIM-based toolkit.

Day 2: Grid-Forming Converters in Renewable Plants and Microgrids – Prof. Rolando Burgos – VT

- Modelling and stability analysis of three-phase converters using impedance-based approaches.
- Impact of grid-following and grid-forming inverters in renewable energy systems and their interaction with the power grid.
- Operation of grid-forming converters in renewable plants and microgrids, including fault coordination and black-start capability.
- Hands-on session: MATLAB-based tools for impedance measurement and stability assessment of converter-dominated systems.

Day 3: Grid-Forming Converters for Power System Stability – Prof. Oriol Gomis-Bellmunt – UPC

- Applications of grid-forming technology in HVDC systems, STATCOMs, hybrid AC-DC networks and emerging grid-forming loads.
- Power system stability improvement using grid-forming converters, including oscillation damping and dynamic grid support.
- Transient stability, fault ride-through behaviour, phase jumps and current-limiting control strategies.
- Hands-on session: analysis of power systems with grid-forming converters using the VeraGrid open-source software platform.

Form of evaluation: PhD students interested in earning a 3 ECTS certificate from the course professors are required to submit a report following the course. This report should demonstrate their ability to solve fundamental issues related to the modeling and control of GFM. Students must prepare a brief project report on a specific use case provided by the instructors, showcasing their proposed solutions. The instructors will review and grade these reports to determine eligibility for the 3 ECTS certificate.

INSTRUCTORS

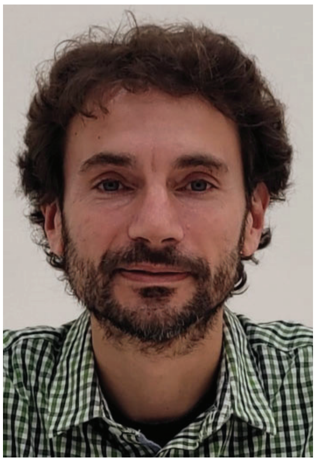
Pedro Rodriguez (Fellow and Distinguished Lecturer, IEEE) received his M.Sc. and Ph.D. degrees in electrical engineering from the Technical University of Catalonia (UPC), Spain (1994 and 2004, respectively). He was a postdoc researcher at the CPES, Virginia Tech, US, at the Department of Energy Technology, Aalborg University (AAU), Denmark and at the MIT Energy Initiative (MITie), Boston, US. He was a co-supervisor of the Vestas Power Program, Denmark (2007 – 2011). He was a director of technology on Modern Power Systems at Abengoa Research (2011- 2017). He was the head of Loyola.Tech, at Loyola University, Spain (2017-2020). From 2021, he is with the Luxembourg Institute of Science and Technology (LIST), Luxembourg, where he leads a unit on Intelligent Clean Energy Systems (ICES). He is also linked with the UPC as a part-time professor. He has been in the Clarivate's list of Highly Cited Researchers in Engineering. He has co-authored one Wiley-IEEE book, more than 100 papers in ISI technical journals, and around 300 papers in conference proceedings. He is the holder of 17 licensed patents. He has participated in more than 50 projects with industrial partners and several EU projects.

Dr. Rodriguez is an IEEE Fellow and a Distinguished Lecturer for his contributions in the control of distributed generation. He was entitled Honoris Causa Doctorate by the Aalborg University, Denmark. He was honored with the 2020's Sustainable Energy Systems Technical Achievement Award by IEEE Power Electronics Society (PELS) and the 2025's IEEE Bimal Bose Award for Industrial Electronics Applications in Energy Systems by IEEE Industrial Electronics Society. (IES). He has served as an Associate Editor of the IEEE Transaction on Power Electronics, IEEE Journal on Emerging and Selected Topics on Power Electronics, IEEE Journal on Industrial Electronics and Energies. His research interests include intelligent energy systems, distributed generation, and universal energy access.

Prof. Pedro Rodriguez, Luxembourg Institute of Science and Technology, pedro.rodriguez@list.lu

Rolando Burgos (Fellow IEEE) received the B.S. on Electronics Engineering, the Electronics Engineering Professional Degree, and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Concepción, Chile, in 1995, 1997, 1999, and 2002 respectively. In 2002 he joined, as Postdoctoral Fellow, the Center for Power Electronics Systems (CPES) at Virginia Tech, in Blacksburg, VA, becoming Research Scientist in 2003, and Research Assistant Professor in 2005. In 2009 he joined ABB Corporate Research in Raleigh, NC, where he was Scientist (2009–2010), and Principal Scientist (2010–2012). In 2010 he was appointed Adjunct Associate Professor in the Electrical and Computer Engineering Department at North Carolina State University at the Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center. In 2012 he returned to Virginia Tech and CPES as associate professor in The Bradley Department of Electrical and Computer Engineering, where he earned an early tenure decision in 2017 and was promoted to professor in 2019. From 2021 to 2025 he served as CPES Director, where he now serves as a member of the CPES Executive Board. His research interests include high power density wide-bandgap semiconductor-based power conversion—low voltage and medium voltage applications, packaging and integration, electromagnetic interference (EMI) and electromagnetic compatibility (EMC), multi-phase multi-level power converters, modeling and control, grid power electronics systems, and the stability of ac and dc power systems. Dr. Burgos is Member of the IEEE Power Electronics Society, the IEEE Industry Applications Society, the IEEE Industrial Electronics Society, and the IEEE Power and Energy Society.

Prof. Rolando Burgo, Virginia Tech, Blacksburg, VA, rolando@vt.edu



Oriol Gomis-Bellmunt (Fellow IEEE) received the degree in industrial engineering from the School of Industrial Engineering of Barcelona (ETSEIB), Technical University of Catalonia (UPC), Barcelona, Spain, in 2001 and the Ph.D. degree in electrical engineering from UPC in 2007. In 1999, he joined Engitrol S.L., where he worked as a Project Engineer in the automation and control industry. Since 2004, he has been with the Department of Electrical Engineering at UPC, where he is currently a Professor and member of the CITCEA-UPC Research Group. Since 2009, he has also been affiliated with the Catalonia Institute for Energy Research (IREC). Since 2020, he has been an ICREA Academia Researcher. In 2022, he co-founded the start-up eRoots Analytics, focused on the analysis of modern power systems.

Dr. Gomis-Bellmunt was elevated to IEEE Fellow in 2021. His research interests include power electronics, electrical machines, renewable energy integration, and the analysis and operation of modern power systems with high penetration of power electronic converters.

Prof. Oriol Gomis-Bellmunt, Technical University of Catalonia, Spain, oriol.gomis@upc.edu

RELEVANT INFORMATION

ECTS: 3 (after positive report evaluation)

Date and Time: 9-11 June, 2026 (9:00 – 17:00)

Place: Luxembourg Institute of Science and Technology (LIST). 41, rue du Brill, L-4422 BELVAUX

Price:

- 800 EUR for PhD students not from LIST, VT, UPC
- 1.100 EUR for industry engineers

Format: In person

Max no. of participants: 15

Lunch: Included

DETAILED PROGRAM

Day 1: Overview of GFM power converters (Prof. Pedro Rodriguez)

- 9h00-9h30 – Course presentation and warming-up discussion
- 9h30-10h30 – Synchronization of grid-connected converters
- *30 min break*
- 11h00-11h30 – Grid following (GFL), grid supporting (GSP) and grid forming (GFM)
- 11h30-12h30 – Virtual synchronous generation. Implementation tree
- *60 min lunch break*
- 13h30-14h00 – Technology evolution: GFM is not a new concept
- 14h00-15h00 – The Synchronous Power Controller as a preferred implementation
- *30 min break*
- 15h30-17h00 – **Hands on:** PSIM toolkit for GFM converters simulation and implementation

Day 2: GFM power converters in renewable and microgrid applications (Prof. Rolando Burgos)

- 9h00-9h30 – Three-phase converter modeling review
- 9h30-10h30 – D-Q frame impedance-based stability review
- *30 min break*
- 11h00-12h00 – Grid impact of GFL and GFM inverters in REN applications
- 12h00-12h30 – GFM PV inverter impact on grid fault coordination and black start
- *60 min lunch break*
- 13h30-15h00 – GFM inverters in microgrids
- *30 min break*
- 15h30-17h00 – **Hands on:** MATLAB toolkit for ac impedance measurement and stability assessment

Day 3: GFM power converters for grid stability improvement (Prof. Oriol Gomis)

- 9h00-10h30 – GFM in HVDC converters, GFM STATCOMS, GFM in hybrid AC-DC systems, and GFM loads
- *30 min break*
- 11h00-12h30 – Power grid stability and damping through GFM. Equivalent circuit of GFM converters under the current limitation mode
- *60 min lunch break*
- 13h30-15h00 – Transient stability analysis, fault ride-through, phase jumps, current limiting and grid support
- *30 min break*
- 15h30-17h00 – **Hands on:** VeraGrid - Open-source software for analysis of grids with GFM converters

Form of evaluation:

- PhD students interested in earning a **3 ECTS certificate** are required to submit a **report following the course**.
- This report should demonstrate their ability to solve fundamental issues related to the modeling and control of GFM. Students must prepare a brief project report on a **specific use case either proposed by the students or provided by the instructors**, showcasing their proposed solutions.
- The instructors will review and grade these reports to determine eligibility for the **3 ECTS certificate**.