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Tutorial Title

Grid Forming Power Converters: Concepts, Implementation, and Analysis

Instructor Team

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Abstract

As the penetration of renewable energy sources driven by grid-connected power converters monotonously increases, unusual interactions between innovative and legacy generation systems become more concerning since they threaten the system's stability and reliability. These undesirable interactions are mainly due to the fact that power converters and conventional electromechanical generators currently work under different physical and control principles and rules. This gives rise to some incompatibilities in terms of dynamic response and physical limits, which has become evident once the share of power converters connected to the grid has become relevant enough. In order to address this issue, the hierarchical control of power converters in electrical grids should be revised, and the modelling and analysis methods should be adapted to the new requirements from systems operators. In this tutorial, we will review the role of grid-connected power converters, paying special attention to the most critical aspects when they work as grid-following converters, i.e., injecting current into a given voltage source provided by the grid, and as grid-forming converters, i.e., energizing an electrical grid 'from scratch' and regulating its operation when heterogeneous generators and loads are connected. We will see how grid forming-converters might be understood as an electronic implementation of the well-known synchronous generators, but well also evidence that not all the features and operation principles of the electromechanical machine invented in the IXX century are of interest to conform the electrical power systems of the future. In this tutorial we will present the operation principle and controllers of grid-forming converters, will analyze their performance and will make an overview of the most relevant implementation approaches reported in the literature. Moreover, we will present in detail a preferred implementation, assessing the services provided to the grid (inertia emulation, power oscillations damping, voltage/frequency regulation, power quality improvement, island operation, black-start, …) under different operation conditions and applications. Finally, we will present some analysis techniques to evaluate the impact of grid-forming converters on the grid performance, paying special attention to dynamic analysis and stability, and providing rules and guidelines for tuning grid-forming controllers.

Instructor Biography

Pedro Rodriguez (S'99-M'04-SM'10-FM'14) 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 Renewable Energy Systems (IRES). 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 (2015-2018). 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 16 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 has been honored with the 2020's Sustainable Energy Systems Technical Achievement Award by IEEE Power Electronics Society (PELS). 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.

Xiongfei Wang (Fellow, IEEE) received the B.S. degree from Yanshan University, China, in 2006, the M.S. degree from Harbin Institute of Technology, China, in 2008, both in electrical engineering, and the Ph.D. degree in energy technology from Aalborg University, Denmark, in 2013. From 2009 to 2022, he was with Aalborg University where he became an Assistant Professor in 2014, an Associate Professor in 2016, a Professor and Leader of Electronic Power Grid (eGRID) Research Group in 2018. From 2022, he has been a Professor with KTH Royal Institute of Technology, Stockholm, Sweden, and a part-time Professor with Aalborg University, Denmark. His current research interests include modeling and control of power electronic converters and systems, stability and power quality of power-electronics-dominated power systems, and high-power converters.

Dr. Wang serves as Co-Editor-in-Chief for the IEEE Transactions on Power Electronics and as Associate Editor for the IEEE Journal of Emerging and Selected Topics in Power Electronics. He was a member at large of Administrative Committee of IEEE Power Electronics Society (PELS) during 2020-2022. He received ten IEEE/IET Prize Paper Awards, the 2016 AAU Talent for Future Research Leaders, the 2018 Richard M. Bass Outstanding Young Power Electronics Engineer Award, the 2019 IEEE PELS Sustainable Energy Systems Technical Achievement Award, and the 2022 Isao Takahashi Power Electronics Award.

Heng Wu (S'17-M'20) is currently an Assistant Professor with AAU Energy, Aalborg University, Denmark. His research interests include the modelling and stability analysis of the power electronic based power systems. He is the member of GB grid forming best practice expert group formed by national grid ESO, UK, and the subgroup leader of Cigre working group B4/C4.93 "Development of grid forming converters for secure and reliable operation of future electricity systems". He is the Chair of IEEE Task Force on Frequency-domain Modeling and Dynamic Analysis of HVDC and FACTS, the member of the technical committee (TC) of European Academy of Wind Energy (EAWE), He is identified as world's top 2% scientist by Stanford University from 2019.