

Tutorial Proposal

1. Tutorial Title

Interaction Among the Grid-connected Converters through Their Synchronization Mechanism

2. Instructor Team: name(s), affiliation(s), and contact information

Instructor-1

Name: Marco Liserre

Email: ml@tf.uni-kiel.de

Affiliation: Christian-Albrechts-Universität zu Kiel, Germany

Phone: 0049 431 880 610 0

Instructor-2

Name: Grahame Holmes

Email: grahame.holmes@rmit.edu.au

Affiliation: RMIT University, Australia

Phone: -

Instructor-3

Name: Paolone Mario

Email: mario.paolone@epfl.ch

Affiliation: Swiss Federal Institute of Technology, Switzerland

Phone: 0041 (0)21 69 32662

Instructor-4

Name: Rongwu Zhu

Email: rzh@hit.edu.cn

Affiliation: Harbin Institute of Technology, Shenzhen, China

Phone: 0086 152 6708 2593

Instructor-5

Name: Roberto Rosso

Email: roberto.rosso@enercon.de

Affiliation: ENERCON, Germany

Phone: 0049 4941 9187 4470

3. Abstract

Electrical power systems are currently transitioning from centralized structures, where most of the power generation comes from small numbers of large power rotating machines, to distributed structures, where much of the power generation comes from large numbers of small power-electronic-interfaced renewable resources. This increasing use of multi-functional power electronic converters (such as STATCOM, DVR, UPFC, UPS and Solid-state Transformer) is challenging the principles of electrical grid operation. One emerging area of concern is harmonic stability issues created by large numbers of grid-connected power converters, with converter synchronization to the grid emerging as a critical factor which can cause anomalous interactions between these converters. This tutorial considers this synchronization issue from the perspective of both the electrical power grid and the converter. The tutorial begins with the electrical grid perspective, looking at limitations of conventional grid modelling approaches in the presence of grid-connected converters, and then presenting advances that have been made in this area. Next, the tutorial reviews grid-synchronization from the converter perspective, looking at modelling issues, established grid-synchronization strategies and grid converter classification implications. The tutorial then presents power synchronization as an emerging alternative for Grid-Forming-Converters, and considers its benefits in comparison to a Phase-Locked-Loop approach. Finally, the tutorial presents the idea of self-synchronization, where the converter synchronizes to internal control loop variables instead of measured voltages, to improve its stability and ride-through capability in the presence of grid harmonics and faults.

4. Tutorial Outline

Topic 1: Power system modeling in the presence of converter-based generation

- 1.1 The context
- 1.2 Adequacy of signal processing techniques
- 1.3 Modeling of harmonic interactions

Topic 2: Classification of grid-connected converters and synchronization strategies

- 2.1 Impacts of modeling accuracy of the converter synchronization on the system performances
- 2.2 Introduction to grid synchronization strategies
- 2.3 Classification of grid connected converters

Topic 3: Impact of synchronization techniques on stability of grid connected converters

- 3.1 Advantages and potential challenges related to power-synchronization mechanism
- 3.2 Approaches for stability analysis of the interactions between converters
- 3.3 Small-signal stability analysis of the interactions between converters in a power-electronics dominated power system

Topic 4 Principles and potential of self-synchronization

- 4.1 Principles of self-synchronization for inverter side current regulation
- 4.2 Harmonic disturbance rejection and stability benefits of self-synchronization
- 4.3 Impact of grid voltage unbalance on self-synchronization

5. Authors' Photos and Bios



Marco Liserre (FIEEE) received the MSc and PhD degree in Electrical Engineering from the Bari Polytechnic, respectively in 1998 and 2002. He has been Associate Professor at Bari Polytechnic and Professor at Aalborg University (Denmark). He is currently Full Professor and he holds the Chair of Power Electronics at Christian-Albrechts-University of Kiel (Germany). He has published over 500 technical papers (more than 159 of them in international peer-reviewed journals) and a book. These works have received more than 35000 citations. Marco Liserre is listed in ISI Thomson report “The world’s most influential scientific minds”.

He has been awarded with an ERC Consolidator Grant for the project “The Highly Efficient And Reliable smart Transformer (HEART), a new Heart for the Electric Distribution System”.

He is member of IAS, PELS, PES and IES. He has received the IES 2009 Early Career Award, the IES 2011 Anthony J. Hornfeck Service Award, the 2014 Dr. Bimal Bose Energy Systems Award, 2017 IEEE PELS Sustainable Energy Systems Technical Achievement Award and the 2018 IEEE-IES Mittelmann Achievement Award, which is the highest award of the IEEE-IES.



Grahame Holmes (FIEEE) graduated from the University of Melbourne in 1974, and has a Masters degree in power systems engineering, and a PhD in PWM theory for power converters. For 26 years he was an academic at Monash University, working in the area of Power Electronics, where he established the Power Electronics Research Group to support graduate students and research engineers working together on a mixture of theoretical and practical R&D projects. The interests of the group include fundamental modulation theory, current regulators for drive systems and PWM rectifiers, active filter systems for quality of supply improvement, resonant converters, current source inverters for drive systems, and multilevel converters. From 2010 to 2020, until his retirement, he held the position of Innovation Professor – Smart Energy at RMIT University, where he expanded his research activities into applications of power electronics for Smart Grids and Smart Energy technologies. He is now an Honorary Professor at RMIT.

He has a strong commitment and interest in the control and operation of electrical power converters. He has made a significant contribution to the understanding of PWM theory through his publications and has developed close ties with the international research community in the area. He has published over 300 papers at international conferences and in professional journals, and has published a major reference book on Pulse Width Modulation of Power Converters which is now recognised as a seminal work in the area. He is a Fellow of the IEEE and is an active member of the IEEE Power Electronics Society and reviews papers for all major IEEE transactions in his area.



Mario Paolone (SMIEEE) received the M.Sc. (Hons.) and Ph.D. degrees in electrical engineering from the University of Bologna, Italy, in 1998 and 2002. In 2005, he was an Assistant Professor in power systems with the University of Bologna, where he was with the Power Systems Laboratory until 2011. Since 2011, he has been with the Swiss Federal Institute of Technology, Lausanne, Switzerland, where he is currently a Full Professor and the Chair of the Distributed Electrical Systems Laboratory.

His research interests focus on power systems with particular reference to real-time monitoring and operational aspects, power system protections, dynamics and transients. He has authored or co-authored over 300 papers published in mainstream journals and international conferences in the area of energy and power systems that received numerous awards including the IEEE EMC Technical Achievement Award, two IEEE Transactions on EMC best paper awards, the IEEE Power System Dynamic Performance Committee's prize paper award and the Basil Papadimas best paper award at the 2013 IEEE PowerTech. Dr. Paolone was the founder Editor-in-Chief of the Elsevier journal Sustainable Energy, Grids and Networks.



Rongwu Zhu (MIEEE) received the PhD degree in Energy Technology from Aalborg University, Denmark, 2015. He is currently a Full Professor at the Harbin Institute of Technology, Shenzhen, China. He was a senior researcher and team leader of renewable grid with the Chair of Power Electronics of the Christian-Albrechts Universität zu Kiel, Germany, from 2016 to 2019, and was a guest scientific researcher at Aalborg University from 2011 to 2012.

He was also the team member of the ERC Consolidator Grant project “The Highly Efficient And Reliable smart Transformer (HEART), a new Heart for the Electric Distribution System”

His research interests include the power electronics technology with focus on the low carbon technology and renewable power system. He has authored or co-authored over 100 technical papers (over 50 of them in international peer-reviewed journals), and held two granted patents as well as four pending patents. He was an organizer and presenter of 5 tutorials at the EPE2021, ECCE2020, ECCEAsia2019, PowerTech2019 and Electromatics2019. He was in recognition for the outstanding contribution as Technical Session Chair in the EnergyCon2020 and for organizing tutorial in the ElectriMacs2019.



Roberto Rosso (MIEEE) received the B.Sc. degree in electronic engineering and the M.Sc. degree in electrical engineering in 2009 and 2012, respectively, from the University of Catania, Catania, Italy. He is currently working toward the Ph.D. degree (since 2017) in electrical engineering at the Christian-Albrechts-University of Kiel, Kiel, Germany.

In 2013, he joined the R&D division of the wind turbine manufacture ENERCON (Wobben Research and Development WRD), where he is currently working at the Control Engineering Department. He has been involved in several research projects addressing analytical models of electrical machines, control of electric drive systems, and control of grid-connected converters, contributing as inventor and co-inventor to several patents held by the company.

His research interests include converter control strategies for grid integration in systems with high penetration of power electronics-based power sources. He is member of the Workgroup GC0137 established by the British System Operator NGESO on minimum specification required for provision of GB grid forming capability.