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Tutorial Title

Converter-Driven Stability Issues and Solutions in Power Electronics Defined Power Systems

Instructor Team

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Abstract

The increasing penetration of inverted based resources (IBRs) and the retirement of synchronous generators (SGs) are leading to rapid transformations in global power systems. As power electronics converters are widely applied across power generation, transmission, and distribution, power systems face unprecedented stability challenges. Compared with the conventional power system stability issues, IBR driven stability issues pose new technical challenges due to the fast dynamics and limited overcurrent capabilities of power electronics converters. On one hand, control interactions between IBRs or between IBRs and other power system devices can cause harmonic oscillations across a wide frequency range. On the other, maintaining grid voltage stiffness becomes challenging when SGs are replaced with power electronics converters due to the limited overcurrent capabilities of power semiconductors. Consequently, power systems are becoming more susceptible to contingencies resulting from reduced grid strength, low inertia and high rates of change of frequency (RoCoF). These converter-driven stability issues should be properly identified and addressed to facilitate the transition toward power electronics defined power systems. This tutorial aims at introducing the power electronics converter driven stability issues through developing effective analysis methods to facilitate system stability demonstration and designing advanced control methods of power converters for stability enhancement. Both small-signal and large-signal stability of power electronics defined power systems will be covered.

This tutorial will firstly cover the impedance based small-signal stability analysis methodologies for power electronics defined power systems, including system modelling, stability assessment and stability-oriented control design. Different approaches to stability analysis such as Nyquist plot, Bode plot, will be explored. The concept of settling angle and the settling angle-based stability criterion will be introduced to facilitate stability analysis of wide-area multi-converter systems, providing insights about instability mode identification and participation factor analysis for both single-bus and multi-bus systems. A case study based on the real-world Australian West Murray Zone oscillation events will be provided as an example of the stability analysis in power electronics defined power system. The second part of the tutorial covers the large-signal stability challenges and enhancement in weak grids with grid-forming (GFM) converters. GFM converters are promising solutions to enhance system stiffness during the transition towards weak grid, while the limited overcurrent capability and power capacity of GFM converters introduce the large-signal synchronisation stability challenges. Following a summary of recent grid events and grid codes related to GFM converters, responses of GFM converters during grid contingencies will be analyzed. Practical aspects, such as the overcurrent capability and power capacity of power converters, are taken into consideration in the stability analysis of GFM converters. Novel synchronisation control structures will be introduced to extend the functionalities of the conventional power-synchronisation loop in GFM converters, realising more responsible GFM design by coordinating physical limitations with grid support functionalities during contingencies. The stability analysis methodologies and stability-oriented control design are critical for ensuring the safe, reliable and stable operation of power electronics defined power systems and further increasing the hosting capacity of IBRs towards the net zero targets.

Instructor Team Biographies

Georgios Konstantinou received the B.Eng. degree in Electrical and Computer Engineering from the Aristotle University of Thessaloniki, Thessaloniki, Greece, in 2007 and the Ph.D. degree in Electrical Engineering from UNSW Sydney (The University of New South Wales), Australia, in 2012. He is currently an Associate Professor leading the real-time simulations laboratory (RTS@UNSW) at UNSW Sydney and an ARC Future Fellow. His main research interests include multilevel converters, power electronics in HVDC, renewable energy and energy storage applications. He is an Associate Editor for IEEE Transactions on Power Electronics.

Shan Jiang received the BSc(Eng) and MEng degrees in electrical engineering from Shanghai Jiao Tong University, Shanghai, China, in 2017 and 2020, respectively, and the PhD degree in electrical engineering from UNSW Sydney, Australia, in 2025. He is working as a Postdoctoral Fellow at UNSW Sydney, Sydney, NSW, Australia. He is the member of IEEE IAS Renewable and Sustainable Energy Conversion Systems Committee and the NGN member of CIGRE Australia. He has published 18 IEEE Transaction papers, with 12 of them as the first author. His current research interests include control design of power converters, and stability analysis of power electronics defined power systems.

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