Guest Editorial: Special Section on Dynamic Performance and Flexibility Enhancement of RES-dominated Power Systems with Grid-forming Converters

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INVERTER-based distributed generation (DG) and renewable energy sources (RESs) are recognized as key elements to address the challenge of economically harvesting energy while, at the same time, achieving net-zero targets. However, inverter-based generation decreases the physical inertia available in the system and increases uncertainty. Moreover, recent studies have highlighted that relatively high integration of DGs/RESs can negatively impact on power grid dynamics, power quality, frequency control, voltage regulation, as well as other control and operational issues. All these issues significantly limit the penetration of DG and RESs.

This Special Section focuses on the control flexibility provided by a special class of inverter-based resources, namely grid-forming (GFM) converters. These converters have the potential to offset the intermittent nature of distributed energy resources, improve the stability margin of the system, and provide control support to the host utility during abnormal conditions. When coupled with energy storage devices, GFM converters can also mimic the behavior of synchronous machines and provide an inertial response that compensates the lack of physical inertia. This may be established by emulating desirable dynamics, such as inertia, droop, and damping properties, by flexible shaping of their output active and reactive power. In summary, GFM converters appear as a very promising solution to improve power grid stability and performance in the presence of high penetration of DG and RESs.

The objective of this Special Section is to showcase the advances in dynamics modeling, analysis, and control of the RES-dominated power systems with GFM converters. In particular, the following directions are considered.

1) Analysis of the impact of GFM converters on the dynamic performance and stability of the grid.

2) Modelling frequency and voltage response of the grid in the presence of high penetration of GFM converters.

3) Transient and steady-state stability analysis of renewables-integrated power grids.

4) Advanced GFM control strategies for grid integration, such as providing virtual dynamics and new control functions.

5) Applications of GFM converters in providing ancillary services and regulation/control support.

6) Applications of GFM converters in improving inertial response, primary control, secondary control, and power quality.

7) Dynamic challenges and solutions in the hybrid operation of GFM converter, grid-following (GFL) converter, and synchronous generator in a microgrid or a power system.

8) GFM technology applications in oscillation damping, transient overvoltage suppression, fault-ride-through control, and protection in the grid.

Among the several high-quality submissions that we have received, we have finally selected 15 papers for this Special Section, which we believe represent well the current state-of-art in the field from both the academic and practical points of view.

The first four papers address modeling aspects. The titles of these papers publications are “Dynamic Analysis of Uniformity and Difference for Grid-Following and Grid-forming Voltage Source Converters Using Phasor and Topological Homology Methods”, “Hybrid Frequency-domain Modeling and Stability Analysis for Power Systems with Grid-following and Grid-forming Converters”, “Series-parallel Sequence Impedance Models of Multi-loop Grid-forming Converters”, and “Resonance Characterization and Frequency-divided Compensation Strategy for Heterogeneous Inverters-paralleled System”.

The contributions in small-signal stability analysis of the power converters integrated power systems are presented in the next six papers, with the following titles: “Grid Strength Assessment Method for Evaluating Small-signal Synchronization Stability of Grid-following and Grid-forming Converters Integrated Systems”, “DC Voltage Control with Grid-forming Capability for Enhancing Stability of HVDC System”, “Safe Reinforcement Learning for Grid-forming Inverter

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Based Frequency Regulation with Stability Guarantee", "Proportion of Grid-forming Wind Turbines in Hybrid GFM-GFL Offshore Wind Farms Integrated with Diode Rectifier Unit Based HVDC System", "A Systematic Small-signal Analysis Procedure for Improving Synchronization Stability of Grid-forming Virtual Synchronous Generators", and "Low-frequency Oscillations and Resonance Analysis of VSG-controlled PMSG-based Wind Generation Systems".

New research achievements in the transient stability area are presented in the eleventh and twelfth papers, the titles of which are, respectively, "Transient Stability Analysis and Improved Control Strategy of PMSG-based Grid-forming Wind Energy Conversion System Under Symmetrical Grid Fault" and "Virtual Power Angle Synchronous Control for Improving Transient Stability of Grid-forming Converters".

Finally, the last three papers, with titles "Grid-forming Control Based on Adaptive Reactive Power Allocation for Offshore Wind Farms Connected to Diode-rectifier-based HVDC System", "Frequency Deadband Control of Grid-forming Energy Storage Inverter in Primary Frequency Regulation", and "Matching Synchronous Machine Control for Improving Active Support of Grid-forming PV Systems with Enhanced DC Voltage Dynamics" address effective control synthesis issues in the RES-dominated power systems.

We would like to thank all participating authors for submitting their works to this Special Section. We are truly thankful to the Guest Editors who have shepherded the reviews of all the papers considered for this Special Section in the most efficient and efficacious manner. We also would like to take this opportunity to acknowledge the tireless cooperation and support of the reviewers. All submissions were reviewed by at least three reviewers to guarantee a thorough review of each paper.

We are also very grateful to the MPCE staff in the editorial office for their administrative and editorial help.

Last but definitely not least, we would like to express our gratitude to Prof. Antonio Gómez Expósito, who provided continuous support, guidance, and advice.