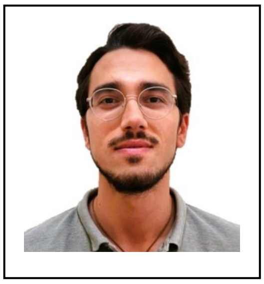
ICSMARTGRID 2025

13TH INTERNATIONAL CONFERENCE ON SMART GRID



Dr. Emanuele Fedele

Naples Federico II, Italy

<u>Abstract</u>

<u>Title: Small-signal modeling and stability analysis of grid-connected converters</u>

With the ever-increasing penetration of renewable energy sources (RES), modern power systems are gradually shifting towards a power-electronic-intensive configuration. Switching voltage-source converters are the key technology for a large-scale integration of renewables and provide many advantages in terms of rapid and flexible control of generation units. Grid-following (GFL) and gridforming (GFM) converters established as the two main control paradigms, and their combined utilization is essential for developing a robust and flexible grid infrastructure. However, their complex control dynamics originating from multiple nested control loops can result in instability issues when interacting with the grid. For this reason, a deep understanding of robust methods to assess the stability of converter-grid interaction is essential to ensure stable and reliable operation of the modern power system.

Oscillations resulting from unstable interactions between the converter and the grid can range from few Hz to several kHz, making the stability assessment a complex task. A typical approach lies in the small-signal modeling and stability analysis of the system. Typically, two main approaches are adopted: state-space modeling with eigenvalue analysis, and transfer-function modeling with frequency-domain analysis, which can be reformulated as impedance-based analysis. The two approaches differ in terms of ease of derivation, insight into oscillations mode and participation factors, scalability, and application to grey and black-box systems.

This tutorial will delve into small-signal modeling and stability analysis of grid-interactive converters. The main concepts behind the state-space and transfer-function modeling of the converter-grid interaction will be detailed, with particular focus on the impedance-based approach. Common mistakes and potential solutions encountered during the application of these methods will be discussed. Ultimately, best practices for extending the stability analysis to a larger interconnected system with multiple converter units will be covered..