

# Coordinated Multi-Loop Control Design of VSM-Controlled DFIGs in Wind Farm to Tackle Intra-Machine Controller Interactions

J. García Aguilar; A. García Cerrada; J.L. Zamora Macho; E.J. Bueno Peña; E. Saiz Marín; A. Muñoz Babiano; M.E. Zarei

## Abstract-

The displacement of synchronous generators by converter-interfaced renewable energy sources requires wind farms to provide inertia, damping, and voltage support, particularly in increasingly weak grids. Based on classical frequency domain loop-shaping techniques, this paper presents a coordinated multi-loop control design methodology for virtual synchronous machine (VSM)-controlled doubly-fed induction generators (DFIGs) in a wind farm to tackle the intra-machine controller interactions. Starting from an initial design and a full small-signal linearisation, the procedure redesigns every local open loop to meet explicit phase margin targets through a single and prioritised iteration. The resulting controllers achieve step responses and stability margins close to those programmed at the design stage, despite the cross coupling between control loops. Results can be improved further if a few more design iterations are carried out. Since the controller synthesis relies exclusively on classical loop-shaping tools available in commercial simulation suites, it is directly applicable to industrial-scale projects.

**Index Terms-** Doubly-fed induction generator (DFIG), frequency-domain analysis, grid-forming (GFM) control, multiloop control, small-signal stability, virtual synchronous machine (VSM), weak grid.

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