Real-Time Reactive Power Limits of Synchronous Generators: Application to the New Spanish Voltage Control System

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Abstract-

The voltage control of the Spanish transmission network faces growing challenges due to the high penetration of renewable energy sources, as evidenced by the Iberian Peninsula blackout on April 28, 2025. Synchronous generators have traditionally ensured voltage stability, but their role becomes even more critical in low-inertia systems with limited synchronous generation. This paper presents a real-time method for computing the reactive power limits of synchronous generators at the network connection point, aligned with the new Spanish voltage control system. The proposed approach determines maximum and minimum reactive power capabilities as functions of active power, network voltage, transformer tap position, and key generator constraints, including armature current, excitation system and stability limits, and admissible voltage ranges. Unlike the conventional p–q representation used by manufacturers, European transmission system operators now define reactive power requirements in the q–v plane. The method reflects this shift by computing and displaying reactive limits in the q–v plane to ensure compliance. The approach is validated with a field test of a 213 MVA hydropower plant, and a simulation test of a 450 MVA single-shaft combined-cycle gas turbine, with sensitivity analyses exploring the impact of key parameters on q–v compliance. Time-domain simulations demonstrate how reactive power limits evolve dynamically in response to changing operating conditions, supporting more accurate and robust voltage control in real time.

Index Terms- Reactive power control, synchronous generators, voltage control

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