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A new fractional-order virtual inertia support based on battery energy storage for enhancing microgrid frequency stability

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Abstract-

Microgrids have a low inertia constant due to the high penetration of renewable energy sources and the limited penetration of conventional generation with rotating mass. This makes microgrids more susceptible to frequency stability challenges. Virtual inertia control (VIC) is one of the most effective approaches to improving microgrid frequency stability. Therefore, this study proposes a new model to precisely mimic inertia power based on an energy storage system (ESS) that supports low-inertia power systems. The developed VIC model considers the effect of both the DC-DC converter and the DC-AC inverter on the power of the ESS used. This allows for more precise and accurate modeling of the VIC compared to conventional models. Moreover, this study proposes a fractional-order derivative control for the proposed VIC model to provide greater flexibility in dealing with different perturbations that occur in the system. Furthermore, the effectiveness of the proposed fractional-order VIC (FOVIC) is verified through an islanded microgrid that includes heterogeneous sources: a small thermal power plant, wind and solar power plants, and ESSs. The simulation results performed using MATLAB software indicate that the proposed VIC scheme provides fast stabilization times and slight deviations in system frequency compared to the conventional VIC schemes. The proposed VIC outperforms the conventional load frequency control by about 80% and the conventional VIC model by about 45% in tackling load/RESs fluctuations and system uncertainty. Additionally, the studied microgrid with the proposed FOVIC scheme is noticeably more stable and responds faster than that designed with integer-order derivative control. Thus, the proposed FOVIC scheme gives better performance for frequency stability of low-inertia power systems compared to conventional VIC schemes used in the literature.

Index Terms- fractional-order virtual inertia control; virtual inertia control; virtual synchronous generator; automatic generation control; battery energy storage; frequency regulation

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