Journal of Energy Storage, vol.62, pp.106952-1-106952-21, June, 2023.

A new two-stage controller design for frequency regulation of low-inertia power system with virtual synchronous generator

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Abstract-

This paper proposes a novel two-stage frequency-regulating control design for modern power systems considering high renewable energy sources (RESs) penetration and electric vehicles (EVs). The proposed controller structure is based on a tilt fractional-order integral derivative (TFOID) in the first stage and a proportional derivative with filter (PDN) in the second stage, referred to as a TFOID-PDN controller. Moreover, this paper proposes a virtual synchronous generator (VSG) based on EVs' batteries that emulate the characteristics of synchronous generators and provide inertia and damping properties, thus restraining the frequency instability problem of future power systems when operating in low inertia. Furthermore, the parameters of both the proposed VSG and the TFOID-PDN controller are fine-tuned using a new reliable metaheuristic optimization algorithm called the artificial hummingbird algorithm (AHA). The efficacy of the proposed TFOID-PDN controller design is examined and investigated through a real large multi-source power system (e.g., Egyptian power system) considering the future scenario in 2035 (i.e., in the presence of high penetration levels of RESs, EVs, and different operating conditions). The superiority of the proposed AHA is validated by comparing it with other powerful optimization techniques such as the marine predators algorithm, grey wolf optimizer, and artificial bee colony optimization through designing the load frequency control based on the PID controller of a well-known two-area interconnected power system. Additionally, the proficiency of the proposed controller is verified over other controllers used in the literature, e.g., fractional-order proportional integral derivative (FOPID), tilt integral derivative (TID), proportional integral derivative (PID), and proportional-integral (PI) controllers, under load/RESs fluctuations. The simulation results carried out by the MATLAB software proved the superior performance of the proposed TFOID-PDN controller compared to other controllers. Moreover, the proposed VSG design prevents modern power systems from reaching instability when operating with a high share of RESs and low inertia.

Index Terms- Electric vehicles; Load frequency control; Power system stability; Renewable energy sources; Two-stage controller; Virtual synchronous generator

Citation:
Nour, M.; Magdy, G.; Chaves, J.P.; Sánchez, A.; Jurado Melguizo, F. "A new two-stage controller design for frequency regulation of low-inertia power system with virtual synchronous generator", Journal of Energy Storage, vol.62, pp.106952-1-106952-21, June, 2023.