

Hybrid tri-level optimal sizing of hydrogen storage for addressing long-term seasonal fluctuation of RES

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Time-varying renewable energy sources (RES), influenced by climate conditions, create seasonal power mismatches. Allocation of hydrogen energy storage (HES) can mitigate long-duration seasonal power mismatch caused by load variation, climate variability and seasonal meteorological conditions. However, one single uncertainty set cannot well consider the characteristics of RES uncertainty in different seasons impacted by long-term climate conditions. To address the above challenges and optimally size and allocate HES in power systems, this paper proposes a hybrid tri-level planning framework that integrates RES interannual long-term and seasonal fluctuation, using a combination of distributionally robust optimization (DRO) and adaptive robust optimization (ARO). Specifically, a RES probability distribution ambiguity set under typical climate conditions is constructed using norm constraints, and data-driven DRO is introduced to address RES long-term uncertainty. RES seasonal uncertainty is then adaptively modelled using multiple uncertainty sets based on the seasonal meteorological characteristics of RES, and ARO is proposed to reformulate the lower-level problem for the worst-case scenarios. The proposed framework is solved using the improved column and constraint generation algorithm (C&CG) with duality-free decomposition. Simulations on IEEE 39-bus system and IEEE 118-bus system confirm the effectiveness of the proposed planning framework and solution algorithm.