Arya Abdollahi, Giulia Amato, Luigi Pio Savastio, Enrico Elio De Tuglie and Desire Dauphin Rasolomampionon, 2026, Synergistic approach for congestion management using hydrogen storage and ancillary services, *Journal of Energy Storage,* Volume 152, Part C, 30 March 2026, 120746.

Highlights

- A synergistic HES and incentive-based demand response framework is proposed for efficient congestion management.
- The multi-objective optimization model minimizes both congestion costs and total system operating costs.
- Information gap decision theory is employed to manage severe uncertainty in renewable energy generation and load demand.

Abstract The increasing penetration of distributed energy resources in distribution networks introduces significant challenges for congestion management due to their inherent uncertainty. This paper proposes a coordinated congestion management framework that synergistically integrates hydrogen energy storage (HES) systems and incentive-based demand response (IBDR) programs under an information gap decision theory (IGDT)-driven multi-objective optimization approach. The HES operates as both an electrolyzer and a fuel cell, enabling bidirectional energy flow and providing long-duration storage capability, while IBDR delivers short-term, cost-effective demand-side flexibility. The IGDT formulation enhances operational resilience under deep uncertainty in renewable generation without relying on probabilistic data. A virtual pareto front-based multi-objective particle swarm optimization algorithm is developed to balance operational cost minimization, congestion mitigation, and emission reduction objectives. The proposed framework is validated on modified IEEE 33-bus and 69-bus distribution networks with multiple DERs and HES units. Simulation results demonstrate up to 95.43% congestion reduction, 17.4% total operating cost savings, and 27.69% emission reduction compared with initial case. Sensitivity analysis further reveals that optimal performance is achieved with 100–125% HES capacity, 20% DR participation, and a risk-neutral IGDT parameter ($\alpha = 0.08$). These results confirm that the coordinated HES-IBDR strategy provides complementary flexibility, enabling sustainable and uncertainty-resilient operation of future smart distribution grids.

Keywords Hydrogen energy storage, Congestion management, Demand response, Emission reduction, Optimization, Information gap decision theory.