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Sensitivity analysis of reliability constrained, eco optimal solar, wind, hydrogen storage based islanded power system

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The global energy expansion strategy has incorporated islanded renewable energy-based power generation systems to electrify remote communities. The development of these renewable energy systems (RES) decreases grid dependency and operational costs. Solar photovoltaic power stations (SPPS) and wind-driven power stations (WDPS) are commonly employed technologies in isolated power systems. However, their intermittent nature poses dependability obstacles. Therefore, the incorporation of storage technology is essential to enhance reliability. This paper presents a sensitivity analysis to determine the optimal, reliable, and cost-effective sizing of a SPPS, WDPS, and hydrogen storage systems (HSS) based power system for case study of Jaisalmer, India. The ideal dimensions of each component are determined in two different cases, each having a unique objective function. The optimal sizing is attained through a metaheuristic optimization method called Butterfly-PSO. Reliability assessment is carried out using Monte Carlo Simulation (MCS) and two key reliability indices, namely ENS and LOLE are taken under analysis. Sensitivity analyses are performed to examine the effects of incorporating or excluding RES and storage elements on system reliability and cost-efficiency. The findings presents that increasing SPPS capacity by one unit changes around LOLE by 13%, ENS by 14%, and LCOE/TLCC by 1%. Varying WDPS capacity changes LOLE by 16%, ENS by 19%, TLCC by 3.3%, and LCOE by 1.4%. Adjusting HSS tank size by one unit affects LOLE by 2%, ENS by 2.6%, and TLCC/LCOE by 0.02%. Case 1 (Min TLCC) offers a more reliable and cost-effective solution than Case 2.

Keywords Hydrogen storage system, Monte Carlo simulation, Butterfly-PSO, Renewable energy systems, Reliability assessment

The global energy expansion strategy increasingly focuses on renewable energy sources (RES) to address climate change and achieve sustainable energy objectives[1]. The swift reduction in renewable energy costs, enhanced energy efficiency, and widespread electrification position RES as a better substitute to fossil fuel-based systems[2]. Generating electrical energy from RES in islanded or remote areas not only cuts operational expenses but also boosts social and economic development in these regions[3]. Islanded power systems hold considerable promise for lowering grid operation costs and enabling electrification in remote areas[3]. Integrating RES with a sustainable storage system offers a strong solution, ensuring reliable power generation and mitigating the intermittency of RES. Effective planning of optimal and reliable islanded power systems necessitates appropriate component sizing, economic assessment, and reliability evaluation[4].

Among various RES, solar photovoltaic power stations (SPPS) and wind-driven power stations (WDPS) are the most commonly used technologies due to the widespread availability of solar and wind resources and their efficient systems[5]. This makes them ideal for islanded power generation. In terms of storage technologies, battery storage is the most prevalent. However, challenges such as self-discharge rates, limited lifespans, and long-term

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