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Optimal sizing of a fixed-tilt ground-mounted grid-connected photovoltaic system with bifacial modules using Harris Hawks Optimization

Abstract

This paper presents an optimal design for ground-mounted grid-connected bifacial PV power plants using a Computational Intelligence (CI)- based Harris Hawks Optimization (HHO) algorithm. This HHO algorithm identifies the best configuration of components and installation parameters for the bifacial PV power plant, aiming to maximize the final yield, minimize the Levelized Cost of Electricity, and boost the Net Present Value. Four variables were optimized: the bifacial PV module model, inverter model, tilt angle, and module elevation. Furthermore, the paper introduces a Harris Hawks Optimization Sizing Algorithm (HHOSA) to address the sizing challenges. The presented HHOSA was purely developed in Matlab R2017b. The usage of PVsyst was only limited to the derivation of irradiation data at different tilt angle of PV array. These data were later used in HHOSA. To verify its effectiveness, HHOSA was benchmarked against other CI algorithms, including the Slime Mould Algorithm (SMA), Firefly Algorithm (FA), Manta Ray Foraging Optimization (MRFO), and Cuckoo Search Algorithm (COA). The evaluation considered the algorithm's stability, local search capability, convergence rate, computation time, and required population size. Findings suggest that the HHOSA outperforms its peers, marking it as a potential leader for designing bifacial PV power plants. The results indicate that the HHOSA algorithm exhibits superior performance in these aspects, making it a promising approach for optimizing the design of bifacial PV power plants. Moreover, this study provides insights into the economic and technical viability of bifacial PV systems under various environmental and system conditions. A sensitivity analysis, focusing on the interplay of three decision variables – albedo values (25 %, 50 %, and 75 %), tilt angles (10°, 25°, and 35°), and module elevations (0.5 m, 1.5 m, and 2 m) – was conducted. It assessed their influence on final yield, additional bifacial PV module yield, Levelized Cost of Electricity, and the system's Net Present Value. The results emphasize the importance of carefully considering the impacts of albedo, module elevation, and tilt angle on the financial performance of bifacial PV installations.

Keywords

Bifacial photovoltaic power plant; Design; Harris Hawks Optimization (HHO); Levelized cost of electricity (LCOE); Net Present Value (NPV); Optimization; Sizing; Yield