Chapter 8
A Comparative Analysis of Meta-Heuristic Algorithms for Optimal Configuration of Hybrid Renewable Energy Systems for Remote Villages

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ABSTRACT

In the search for sustainable and reliable energy solutions, the deployment of hybrid renewable energy systems (HRES) has developed as a promising approach mainly

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for powering remote villages that lack access to centralized grids. The optimal configuration of these systems leads to a complex optimization problem through demanding the application of meta-heuristic algorithms to efficiently direct the massive solution space and recognize the most cost-effective and reliable setup. Numerous meta-heuristic algorithms have been engaged for this purpose. Through a comparative analysis of various meta-heuristic algorithms, particle swarm optimization helps in obtaining improved solutions. Particle swarm optimization (PSO) occurs as a powerful and effective optimization technique in addressing the complex task of determining optimal configurations for hybrid renewable energy systems positioned in remote villages.

INTRODUCTION

Hybrid renewable energy systems represent an innovative and sustainable approach to power generation by integrating multiple renewable energy sources into a single, cohesive system (Natrayan, Kaliappan, Saravanan, et al., 2023). These systems typically combine various renewable technologies, such as solar photovoltaic (PV), wind turbines, biomass, and sometimes small-scale hydropower, to optimize energy production and enhance overall system efficiency (Ragumadhavan et al., 2023). The synergy achieved in hybrid systems allows for a more reliable and consistent power supply, addressing the intermittent nature of individual renewable sources (Selvi et al., 2023). One key advantage of hybrid renewable energy systems is their ability to mitigate the limitations associated with each individual energy source (Kaliappan, Mothilal, et al., 2023; Velumayil et al., 2023). For instance, solar power production is inherently intermittent due to day-night cycles and weather variations, while wind energy is influenced by wind speed fluctuations (Chinta et al., 2023; Suman et al., 2023). By combining these sources, the system can generate electricity more consistently, thus improving overall reliability (Natrayan, Kaliappan, & Pundir, 2023). Additionally, the integration of energy storage solutions, such as batteries, allows for the storage of excess energy during peak production periods for later use during low-production or high-demand periods (Kaliappan, Natrayan, & Rajput, 2023). Energy storage is vital for confirming a continuous power supply. Hybrid systems incorporate batteries and other storage technologies to store excess energy generated during peak times (Kaliappan, Natrayan, & Garg, 2023; Natrayan & Kaliappan, 2023). This helsp in making it available during periods of low or no renewable energy assembly. Hybrid renewable energy systems are designed to be cost-effective by extracting the strengths of multiple renewable sources. The installation and maintenance costs are offset by long-term savings and reducing the environmentally harmful fossil fuels (Josphineleela, Kaliapp, et al., 2023).

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