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An Improved Multi-Objective Brain Storm Optimization Algorithm for Hybrid Microgrid Dispatch

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ABSTRACT

The increasing integration of renewable energy sources into microgrids has led to challenges in achieving daily optimal scheduling for hybrid alternating current/direct current microgrids (HMGs). To solve the problem, this article presents a novel hybrid AC/DC microgrid scheduling method based on an improved brain storm optimization (BSO) algorithm. Firstly, with economic and energy storage device health as the primary objective functions, this paper proposes a dispatch model for AC-DC hybrid microgrids. To overcome the limitations of traditional algorithms, including premature convergence and can only find non-inferior solution sets, this article proposes a multi-objective BSO algorithm that integrates learning and selection strategies. Additionally, a fuzzy decision-making method is employed to achieve optimal daily dispatching and select the most suitable compromise solution. Finally, experiments are conducted to verify the effectiveness of the proposed multi-objective optimal scheduling method and to demonstrate the practicality and effectiveness of the method in real application scenarios.

KEYWORDS

Alternating Current/Direct Current, Brain Storm Optimization, Fuzzy Decision Making, Microgrid, Multi-objective Optimization

INTRODUCTION

With the increasing demand for electricity, the structure of the power grid is becoming more and more complex, with centralized power generation, large grids for long-distance transmission and other traditional grid structures also facing more challenges, including high costs, difficulty in operation, and difficulty in meeting the user's requirements for high quality, high reliability power and diversified power supply needs. In order to make the power grid run more securely and economically, the smart grid with distributed power supply as the main unit came into being. However, when a power system failure occurs, distributed power supply must immediately withdraw from operation, which limits the role of distributed power supply.

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In order to enhance the benefits of distributed power sources, microgrids have emerged. A microgrid is a small-scale power generation and distribution system consisting of distributed power sources, energy storage devices, energy conversion devices, loads, monitoring and protection devices, and the like. Microgrids effectively reduce the impact of photovoltaic (PV) and wind power output uncertainties on the traditional power grid (Das et al., 2022). To enhance microgrid development and leverage the advantages of AC and DC microgrids in managing renewable energy output uncertainties, the concept of AC/DC HMGs has emerged. These hybrids combine the strengths of AC and DC microgrids, offering a flexible energy management approach (Faraji et al., 2022; Zand et al., 2020; Zhang et al., 2018). They can accept both AC and DC energy sources, converting and controlling them through power electronic devices to accommodate various energy inputs (Ansari et al., 2020). As a result, AC and DC renewable energy sources can be seamlessly integrated into the AC/DC HMGs (Heidari et al., 2022; Jayaram et al., 2022).

The increasing penetration of renewable energy sources in AC/DC HMGs poses challenges for energy management (Ansari et al., 2020). Distributed energy storage systems play a vital role in addressing these challenges and find applications in different aspects of AC/DC HMGs (Elgamal et al., 2022). At the micro-power level, these systems can be efficiently scheduled and managed. However, micro-power sources, like photovoltaic generator sets and wind turbines, often exhibit fluctuating power output. Energy storage systems help balance energy supply and demand by storing excess energy for later use or releasing energy when needed to meet load demands. At the electric load level, distributed energy storage systems can be dispatched and managed as well. These systems store power during periods of low load demand and high renewable energy output, releasing power when load demand is high but renewable energy output is low (Gunantara, 2018). This scheduling balances the difference between grid load and supply, reduces pressure on the conventional power system, and enhances overall stability (Marler & Arora, 2004).

The scheduling optimization problem for AC/DC HMGs refers to finding an optimal scheduling strategy to maximize the operational benefits of the microgrids and satisfy the constraints of voltage, power, and security, taking into account the structural and electrical characteristics of the hybrid AC/DC HMGs, the uncertainty of distributed power sources and loads, market tariffs, and operating costs. Both domestic and international scholars have made notable progress in addressing the problem. For instance, Zhang et al. (2022) proposed a day-ahead scheduling algorithm to improve the energy independence, operational reliability, and economy of port microgrids with a two-phase model. Nawaz et al. (2023) introduced a mixed integer quadratic programming method for energy scheduling of islanded multi-microgrids to balance subgrids' supply and demand, reduce battery degradation, and extend cycle life. Shotorbani et al. (2021) developed a multi-objective real-time environmental management system that considers energy costs and life cycle environmental impacts, using the Lyapunov optimization method to optimize the scheduling of distributed energy storage units. Agrawal et al. (2023) modeled the optimal energy flow (ORF) management problem in a hybrid power system containing multiple energy sources and proposed a multi-objective optimization algorithm integrating an innovative nondominated sorting and congestion distance strategy to deal with the ORF problem and improve the reliability of the system. To solve the uncertainty problem in hybrid power systems, a novel hybrid evolutionary algorithm was proposed by Avvari et al. (2023). Zhang et al. (2023) developed an improved NSGA-III algorithm with a dynamic constraint relaxation mechanism and elimination strategy for efficient multi-objective solving.

Although the existing literature has made many contributions to the AC/DC HMGs scheduling problem, there are still some problems, such as a single mathematical model, failure to consider the consumption of the power transmission process, and the fact that only a set of non-inferior solution sets can be found instead of optimal solutions. In order to solve the above problems, we model the AC/DC HMGs scheduling optimization problem by considering the effects of various factors and propose an improved multi-objective BSO algorithm to solve the AC/DC HMGs scheduling optimization problem. The contributions of this paper are as follows: