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13TH INDES 2024

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THE 13TH INTERNATIONAL INNOVATION, INVENTION & DESIGN COMPETITION 2024

EXTENDED ABSTRACTS

e-BOOK

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REFERENCE-POINT MODIFIED HONEY BADGER ALGORITHM: INTELLIGENT OPTIMIZATION FOR OFF-GRID PHOTOVOLTAIC SYSTEM

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ABSTRACT

To address the intricate balance between technical reliability and economic viability in off-grid photovoltaic (PV)-battery-diesel generator systems, particularly in regions without grid access, this study introduces the Reference-Point Modified Honey Badger Algorithm (RP-MHBA) as an innovative optimization methodology. RP-MHBA enhances the conventional Honey Badger Algorithm (HBA) by offering a more comprehensive range of alternative solutions through a Pareto front that trades off between conflicting technical reliability and economic viability, facilitating the discovery of balanced solutions. Consequently, the resulting optimized off-grid PV-battery-diesel generator systems provide a reliable energy supply and yield economic and environmental benefits. Through increased adoption of renewable energy and cost-effective energy provision, this innovation supports entities like TNB, SEDA, and MOSTI in advancing national electricity generation and harnessing artificial intelligence for PV system optimization. Furthermore, this aligns with the United Nations Sustainable Development Goal (SDG) 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all.

Keyword: off-grid photovoltaic, multi-objective optimization, modified honey badger algorithm

1. INTRODUCTION

The reference-point modified honey badger algorithm (RP-MHBA) is a sizing optimization solution for AC-coupled off-grid photovoltaic (PV)-battery systems. The optimization process involves determining the best combination and sizing of PV panels, battery storage, inverters, and diesel generators to ensure a reliable, efficient, and cost-effective power supply. The RP-MHBA improves upon the conventional honey badger algorithm (HBA) by introducing an additional parameter based on the Euclidean distance from a reference point. This enables the algorithm to find configurations that achieve a trade-off between technical reliability and economic viability objectives.

2. METHODOLOGY

2.1 System Description

The AC-coupled off-grid system integrates solar PV, batteries, inverters, and a diesel generator, as shown in Figure 1, to provide a reliable and sustainable energy solution for rural electrification. The system has a database containing multiple models of PV modules, batteries, bi-directional inverters, grid-tie inverters, and diesel generators. Combining these different models results in 8,640 unique system configurations. Optimizing technical reliability and economic viability is crucial for various possible configurations. To address this multi-objective optimization problem, a novel approach called the reference-point modified honey badger algorithm (RP-MHBA) is developed. The RP-MHBA integrates reference point-based into the honey badger algorithm (HBA), a recently proposed nature-inspired metaheuristic technique. This algorithm simultaneously optimizes the technical and economic performance of the system, enabling the identification of the most suitable configuration that achieves a balanced trade-off between technical reliability and economic viability while allowing customization based on specific requirements and conditions.

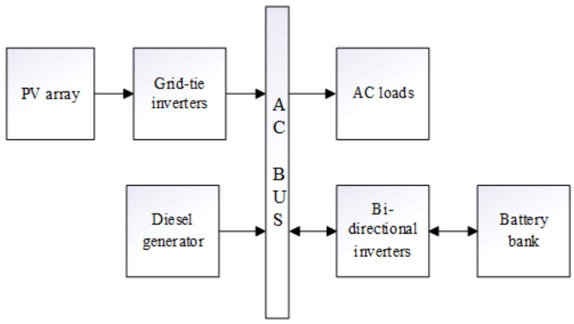

Figure 1 System configuration of off-grid PV-battery-diesel generator system

2.2 Development of reference-point modified honey badger algorithm

The first step involves defining the optimization objectives encompassing the system's technical and economic performance. These objectives include minimizing the loss of power supply probability (LPSP) for technical performance and minimizing the levelized cost of electricity (LCOE) for economic performance. A reference point value for the desired LPSP and LCOE target is established as a baseline for optimal solutions.

Next, within RP-MHBA, fitness values are computed using the Euclidean distance between each solution's fitness point and a predefined reference point in the objective space. Solutions with the minimum distance from the reference point are considered Pareto front candidates, representing trade-offs between technical and economic performance.

The RP-MHBA algorithm iteratively updates the population, generates new solutions, and evaluates their fitness based on the Euclidean distance from the reference point. Solutions dominating the reference point are recorded, and Pareto optimal solutions within the population size are gradually built until termination criteria are met. Ultimately, the Pareto optimal solutions associated with the reference point are obtained, representing the best trade-off solutions. Figure 2 presents the overall framework of RP-MHBA development for the sizing optimization process.

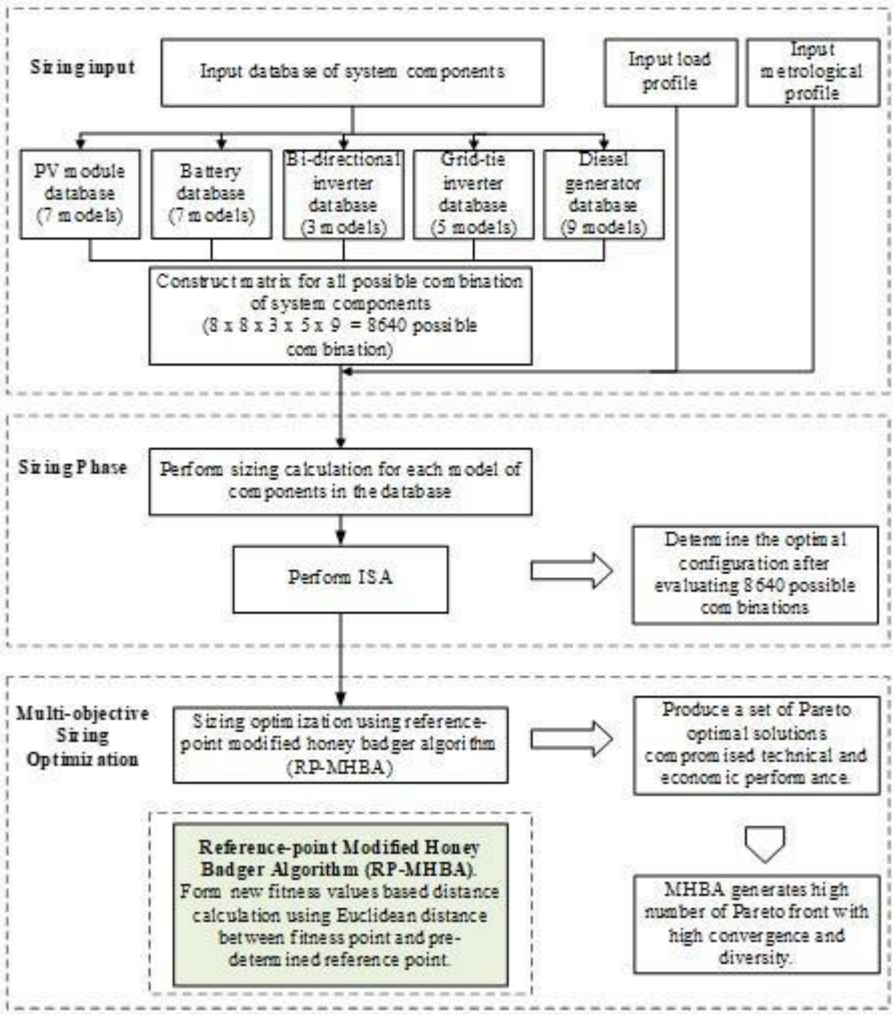

Figure 2 RP-MHBA framework

3. FINDINGS

The performance of RP-MHBA is compared with reference-point HBA (RP-HBA) and weighted-sum method MHBA (WSM-MHBA). Figure 3 presents the distribution of the Pareto front of RP-MHBA against RP-HBA and WSM-MHBA. Based on the figure, RP-MHBA demonstrated superior performance in generating well-distributed and diverse Pareto optimal solutions across the solution space for the trade-off between technical and economic objectives compared to other methods, which yielded fewer optimal points with limited distribution due to the overlapping points at specific weight variations or reference points. Then, the performance of the RP-MHBA is validated by its low inverted generational distance (IGD) (6.5x10-5) and high hypervolume (HV) (7.1625x10-5) values, indicating better convergence towards the actual Pareto front and maintaining solution diversity, as shown in Figure 4. The computational time presented in Table 1 indicates that RP-MHBA is the fastest in simulation time.

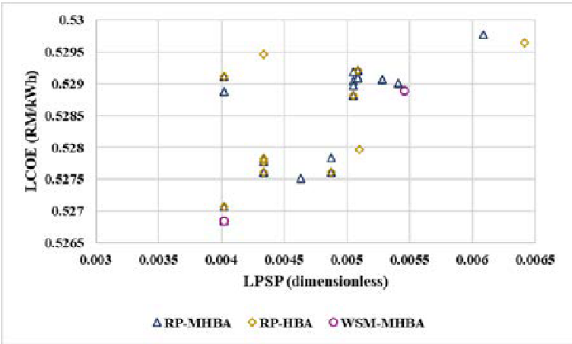

Figure 3 Pareto front distribution of RP-MHBA against RP-HBA and WSM-MHBA

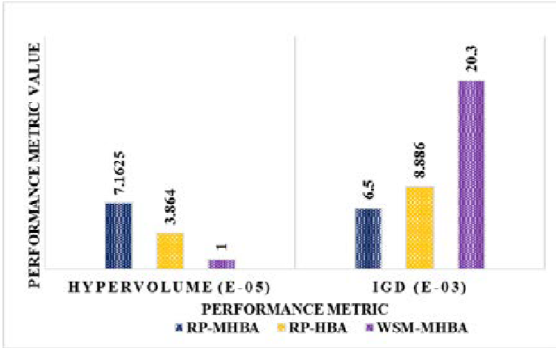

Figure 4 Performance of RP-MHBA based on performance metric

Table 1 Pareto front generation and total computation time of RP-MHBA, WSM-MHBA and RP-HBA

	RP-MHBA	RP-HBA	WSM-MHBA
Pareto front generation	18	11	7
Simulation time,s	178.4	3886.9	182.76

4. CONCLUSION

The RP-MHBA represents a significant advancement in sizing optimization for AC-coupled off-grid PV-battery-diesel generator systems. Its novelty is modifying the HBA's parameters using Euclidean distance to solve simultaneous technical and economic optimization, which can generate a diverse set of high-convergence Pareto optimal solutions. Its implementation offers reliability, economic viability, environmental sustainability, and social development benefits through increased efficiency, cost savings, reduced emissions, and reliable energy access in remote areas. The RP-MHBA has significant commercialization potential for off-grid applications, enabling renewable energy utilization and promoting sustainable solutions. Furthermore, by providing modern, reliable, and sustainable energy access, the RP-MHBA contributes to achieving SDG 7, ensuring affordable, reliable, sustainable, and modern energy for all.

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