A Review on Combined Economic and Emission Dispatch in Microgrid using Various Optimization Techniques

Nitin Goel[1], Naresh Kumar Yadav[2], Naresh Kumar[3]

[1]Research Scholar, Department of Electrical Engineering, DCRUST, Murthal, India
[2,3]Department of Electrical Engineering, DCRUST, Murthal, India

Abstract

With ability to enhance the reliability and security in the power supply, reduced greenhouse gas emissions, and integration of renewable energy sources Microgrids are becoming more popular in electrical systems. However, large scale integration of renewable energy sources can cause power imbalances and uncertainties in the output of electrical interaction sources. Therefore, obtaining an optimal solution for Economic Dispatch (ED) of Distributed Energy Resources (DERs) is critical. While traditional ED models do not include the environmental effects of power generation, there is a need for a CEED (Combined Economic and Emission Dispatch) model that addresses both economic and environmental objectives in the ED problem. Several studies have proposed CEED models for microgrids using lot of optimization methods, based on conventional methods, Artificial Intelligence techniques, Metaheuristic method and hybrid methods. However, the limitations of conventional methods, Multi-Objective Evolutionary Algorithms (MOEAs), Fuzzy Logic, Neural Network, Artificial Neural Networks (ANNs) and Genetic Algorithm (GA) increase with the inclusion of additional objectives and constraints, leading to computational difficulties. Nature inspired optimization algorithms are more useful for solving CEED problem in microgrids. These algorithms are inspired by the nature of social creatures, similar as ants, fish, bee and birds. These nature inspired algorithms have lot of advantages like robustness, scalability and fast convergence over conventional optimization techniques. Various nature inspired metaheuristic optimization techniques used for CEED in microgrids are BA-Bat Algorithm (BA), PSO-Particle Swarm Optimization, ACO-Ant Colony Optimization, FA-Firefly Algorithm and ABC-Artificial Bee Colony etc. Recently, hybridization of optimization techniques is used for CEED in microgrids like GA-PSO hybrid algorithm, GA-ACO hybrid algorithm, PSO-DE hybrid algorithm, PSO-GWO (Grey Wolf Optimizer) hybrid algorithm etc. The presented review paper gives the overview of swarm intelligent based (behavior of social animals based) algorithms for CEED in microgrids and discusses the features and challenges of existing optimization techniques for CEED in microgrids.

Keywords: Microgrid, , Economic Dispatch (ED), Distributed Energy Resources, Nature Inspired Optimization Algorithm, Combined Economic and Emission Dispatch(CEED)

1. Introduction

Background and motivation

Microgrids have recently emerged as an innovative and promising technology in the area of power systems [1]. An energy storage system (ESS), a diesel generator, a solar (PV) photovoltaic system, a wind turbine, and other DERs constitute a microgrid, like a small-size power grid [2]. Microgrids can increase the security and dependability of the power system, lower greenhouse gas emissions, and renewable energy sources (RESs) integration because they can work in grid-connected as well as islanded modes [3].

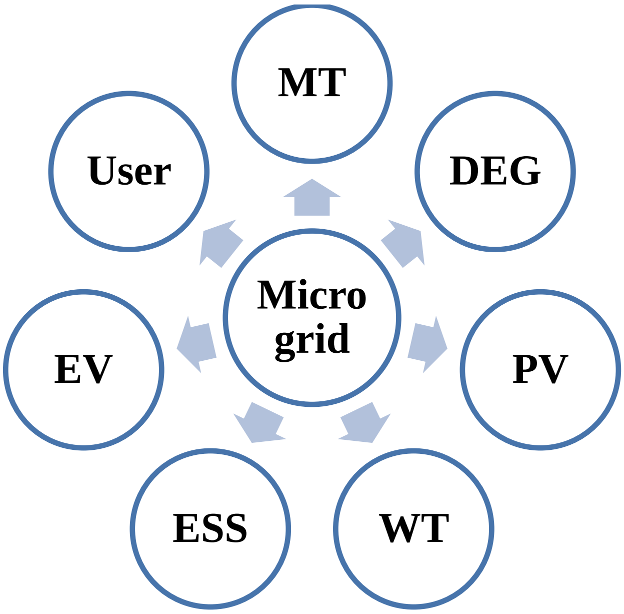

Fig-1 Microgrid (MG) structure

High levels of renewable energy sources can be integrated into microgrids, however, this can present technical difficulties such as frequency and voltage fluctuations, power imbalances, and uncertainty in the output of intermittent sources [4]. Consequently, it is necessary to ensure the efficient and smooth function of microgrids while reducing the adverse effects on the environment by power generation [5]. Economic Dispatch (ED) of DERs, which entails determining the best possible combination of power outputs that minimize overall operating costs while satisfying load demand and operational restrictions, is one of the major challenges in microgrid operation [6].

In [7] some conventional optimization methods like LP-Linear Programming, NLP-Nonlinear Programming, and MILP- Mixed-Integer Linear Programming are used for solving the ED problem [7]. Traditional ED models do not take the environmental effects of power generation into consideration and are therefore unable to give a complete solution to the problem [8]. Consequently, a combined economic and environmental dispatch (CEED) model is required, one that takes into account the economic and environmental objectives in the economic dispatch problem.

Several research works have put forward CEED models for microgrids, including Multi-Objective Evolutionary Algorithms (MOEAs), fuzzy logic and ANNs [9]. Still, success of these models depends upon the fineness of the modeling of the DERs and the optimization algorithms employed [10]. In addition, the complexity of the models goes up when addition objects and constraints, which can lead to computational issues [11].

Currently, researchers have been exploring the eventuality of Swarm intelligence (SI) algorithms for CEED in microgrids [12]. These algorithms are based on the collective nature of creature such as insects, birds and ants etc [13]. They've been proven to be useful in resolving different optimization issues, including those related to CEED in microgrids [14]. SI algorithms have advantages over traditional optimization ways, including their robustness, scalability, and their capability to reach global confluence [15]

Objective of the Review

This review aims to show a comprehensive summary of the rearmost advancements in CEED models for microgrids, with an emphasis on approaches grounded on swarm intelligence (SI). The paper delves into the difficulties and possibilities of CEED for microgrids, the different optimization methods employed in CEED, and the merit and demerits of SI approaches. Also, this review work provides a thorough evaluation of current literature on the subject, go through the research gaps and implicit areas for unborn disquisition in CEED for microgrids.

2. Microgrid Overview

A microgrid is a compact power system that can function autonomously or link with the primary grid to deliver dependable and efficient energy services to a limited community, establishment, or even an individual structure. Microgrids can merge diverse dispersed energy sources such as solar system, energy storage system, wind energy system, and backup generators to enhance power supply use and minimize expenses.

A microgrid is defined as an integration of energy system containing distributed energy resources and interconnection of loads that can operate either autonomously or connected to the grid. [75]

A microgrid typically consists of four main components: [76]

- Distributed Energy Resources (DERs): DERs are small power generation units that can be easily connected to the grid or run independently. Examples include solar panels, wind turbines, and small-scale generators.
- Energy Storage System (ESS): ESS provides backup power during outages, store excess energy generated by DERs, and release it when needed.
- Power Conversion System (PCS): PCS converts the DC power generated by DERs to AC power used by the loads and vice versa.
- Microgrid Controller (MC): MC manages the overall operation of the microgrid, optimizes energy use, and ensures system stability and reliability.

There microgrids can classified based on their connection to the grid and type of load they serve. Microgrids can be classified into three categories[77]:

- Grid-connected microgrid: A microgrid that allows both power connection and isolation.
- Off-grid microgrids: A microgrid that operates separately from the main grid and relies solely on DER and ESS for power.
- Hybrid microgrids: A microgrid that combines grid-tide and off-grid functionality for greater flexibility and resilience.

3. Combined Economic and Emission Dispatch (CEED)

In a power system CEED is a critical optimization problem that deals with the joint optimization of economic and environmental objectives. The primary objective of CEED to overcome the operating cost of the power system while fulfilling the emission constraints. CEED plays an essential role in reducing the operational cost and emissions of power systems while maintaining the reliability and stability of the system. [78]

Several algorithms for CEED problem solving have been proposed by the researchers, such as mathematical programming, evolutionary algorithms, and swarm intelligence algorithms. Mathematical programming methods, like linear and non linear programming (LP and NLP), have been widely used for solving the CEED problem. Evolutionary algorithms, such as GA, Differential Evolution and PSO, have also been applied for getting solution of CEED problem. Furthermore, for getting CEED solution SI algorithms, such as ACO-Ant Colony Optimization and ABC-Artificial Bee Colony, have been proposed. [79]

When it comes to solving the CEED problem, there are several obstacles that must be overcome. One of the most significant challenges is the nonlinearity and non-convexity of the problem, which can make it difficult to find optimal solutions. Additionally, the large-scale nature of the problem can lead to a significant computational burden, which can make it difficult to find solutions in a reasonable amount of time.

Another challenge associated with the CEED problem is the uncertainty in the system parameters. The power system is a complex network of components that are subject to a many factors, like weather patterns and equipment failures. These factors can introduce uncertainty into the system, which can make it difficult to predict how the system will behave under different conditions [19].

Despite these challenges, various optimization algorithms have been used to get solution of the CEED problem. However, there is still a need to improve the efficiency and effectiveness of these methods. Researchers and engineers are working to develop new algorithms and techniques that can address the challenges associated with the CEED problem and help optimize power systems for maximum efficiency and reliability.

4. Optimization Techniques

Different optimization techniques used for economics dispatch, emission dispatch and Combined Economics and Emission Dispatch (CEED) problems. Generally, optimization techniques are categorized into four major types as depicted in Figure 2.

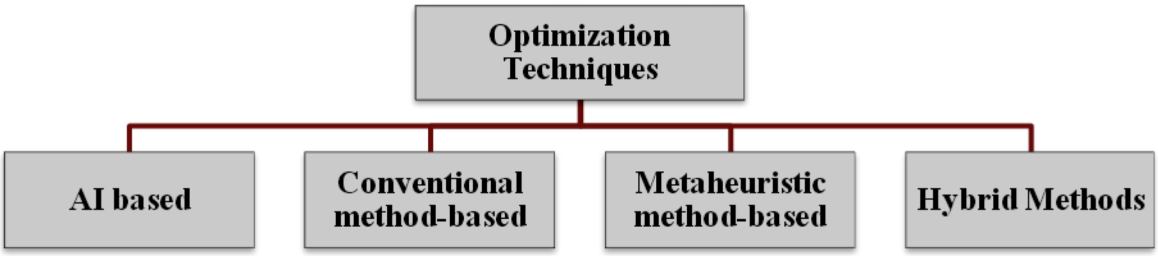

Fig-2 Major classification of optimization techniques

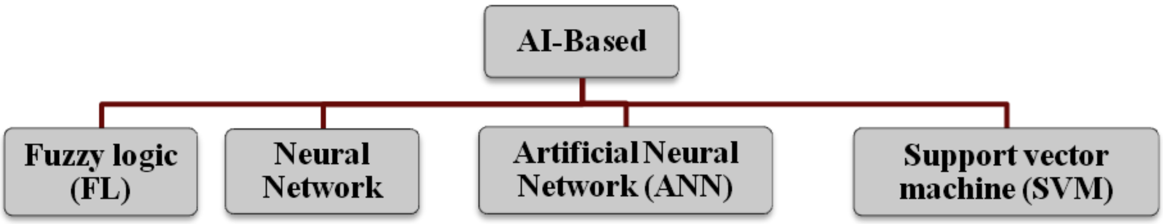

Fig-3 AI based Optimization Techniques

AI-Based Optimization Techniques

AI-based optimization strategies are essential for addressing the complex economic and environmental dispatch problem. These techniques are successful in achieving a balance between minimize the electrical production cost and reducing environmental impact of energy production. AI based optimization techniques shown in fig-3

Conventional Method-Based Optimization Techniques

Traditional methods of optimization, such as linear programming and quadratic programming, are essential for solving CEED issues in power systems. These approaches take into account both economic and emmission objectives at the same time, and help to identify the most efficient way of allocating generation resources to satisfy the load requirement while reducing emissions and operational charges. Fig-4 shows the conventional method based optimization techniques.

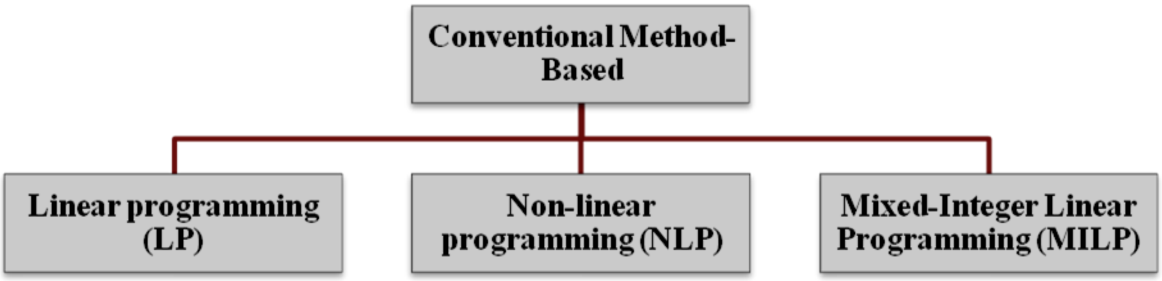

Fig-4 Conventional Method Based Optimization Techniques

Metaheuristic Method-Based Optimization Techniques

Metaheuristic methods are essential in solving CEED problems as they can handle large-scale optimization problems with multiple objectives and constraints. These techniques can efficiently search for optimal solutions while optimize economic and emission considerations, leading to better energy management and sustainable development. Fig 5 shows the list of metaheuristic method-based optimization techniques.

Hybrid Method-Based Optimization Techniques

Hybrid method-based optimization approaches utilize the advantages of various algorithms to produce more efficient and beneficial solutions for combined economic and environmental dispatch issues. These strategies provide a better equilibrium between cost and environmental effect, making them essential for the sustainability of power systems. Some hybrid algorithm techniques are presented in fig-6:

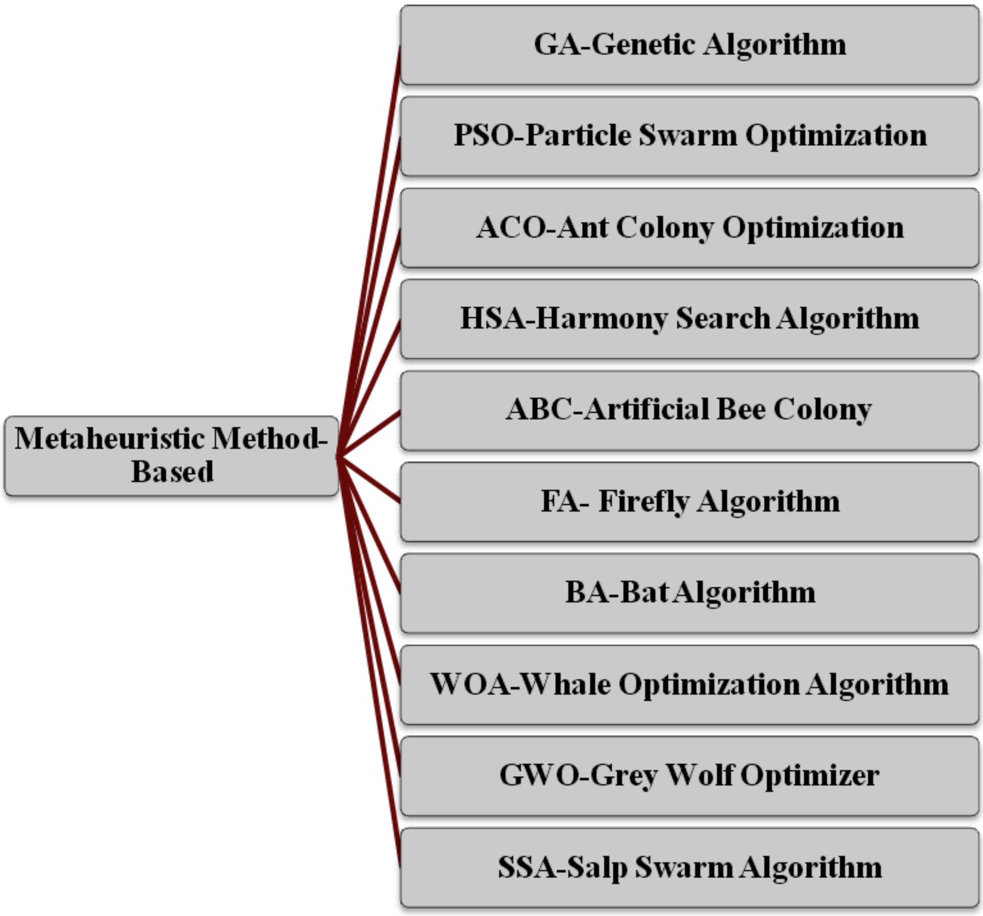

Fig-5 Metaheuristic Method-Based Optimization Techniques

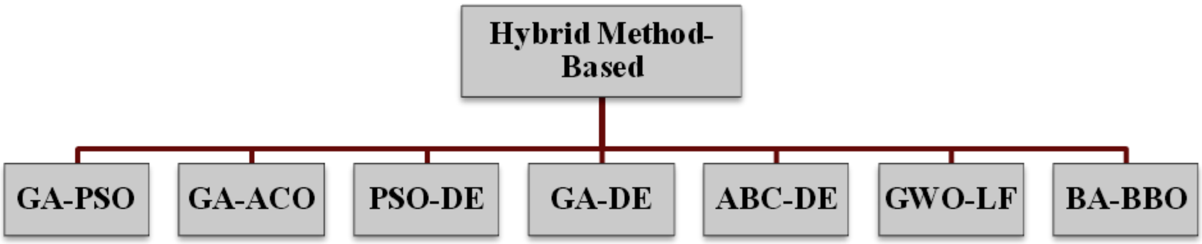

Fig-6 Hybrid Method-Based Optimization Techniques

5. Optimization Techniques for CEED in Microgrid

Economic Dispatch is one of the primary operational challenges in microgrid management. Several studies have proposed various optimization techniques for ED in microgrids, including mathematical programming, Artificial Intelligence (AI), and Metaheuristic Algorithms [16]. However, the increasing integration of Renewable Energy Sources (RESs) in microgrids has led to the need for a more comprehensive solution that considers both economic and emission constraints. Thus, the CEED problem has gained significant attention in the literature.

Conventional method-based, studies have proposed the use of optimization techniques, like LP, NLP and MILP, to solve the CEED problem in microgrids. In [53] MILP algorithm has been used for solving the CEED model. Research results showed that the proposed model achieved better reductions in carbon emissions than traditional allocation methods. However, these models have limitations in incorporating the environmental impacts of power generation [17]. MOEA (Multi-Objective Evolutionary Algorithms) have been used to solve CEED problems, but the high computational cost and the difficulty of finding the Pareto-optimal front limit their applicability [18].

Artificial Intelligent (AI) base optimization techniques have proposed, such as Neural Network, ANN and Fuzzy ANN to solve the CEED problem in microgrids. Fuzzy logic-based approaches have been implemented for the solution of CEED problem, but they require extensive knowledge of the system and have limited scalability [19]. Artificial neural networks (ANNs) have been used to solve CEED problems, but they have drawback of over fitting and slow convergence [20, 48]. Similarly, in [49] CEED model has been proposed using the Fuzzy-ANN algorithm [49] and these techniques have shown great potential in solving the CEED problem in microgrids. But AI algorithms have limitations such as limited scalability, overfitting, and slow convergence, among others. These limitations affect the efficiency and effectiveness of AI base algorithm, especially when apply for complex problems like CEED problem. Many researchers have been exploring various robust and efficient optimization techniques to overcome these limitations. The purposes of these techniques are to enhance the scalability, generalization, and convergence of AI-based optimization algorithms.

For CEED in microgrids, swarm intelligence (SI) algorithms have emerged as a promising strategy. The collective behavior of social animals like ants, bees, and birds is the inspiration for a class of optimization algorithms called SI algorithms [21]. These calculations enjoy a few upper hands over customary improvement procedures, including strength, versatility, and worldwide union. To find the solution of ED and CEED in microgrids, SI algorithms have been used [22].

According to research studies [23, 43], the Particle Swarm Optimization (PSO) algorithm is one of the swarm intelligence algorithms that is utilized the most frequently for CEED in microgrids. A population of particles that mimic the behavior of a flock of birds searching for food serves as the foundation for this algorithm. The algorithm's goal is to find the best solution by updating each particle's position and speed in the search space based on its best individual solution and the swarm's best global solution [24]. Given its effectiveness, the PSO algorithm has been employed in solving various optimization problems in power systems, including CEED and ED problems in microgrids [25].

Another popular SI algorithm is ACO (Ant Colony Optimization) algorithm that has been used for solving the CEED issue in microgrids. Like the PSO algorithm, ACO is a population-based algorithm that simulates the foraging behavior of ants searching for food. The algorithm consists of a set of artificial ants that deposit pheromones on the search space to guide the search for the optimal solution. The pheromone trail is updated based on the quality of the solutions found by the swarm [26]. ACO has been applied for giving solution of different optimization problems in power systems, including ED and CEED problems in microgrids [27, 44]. Similarly, a CEED model has been proposed using the ABC algorithm [45]. These algorithms have shown good global search ability and robustness in solving the CEED problem.

The Firefly Algorithm (FA) is also a SI algorithm that has been used for CEED in microgrids [29]. FA is also a population based algorithm that simulates the flashing behavior of fireflies. The algorithm consists of a set of artificial fireflies that move in the search space to determine the optimal solution. The attractiveness of each firefly is found by its brightness, which is updated based on distance between fireflies and their fitness values [28]. Some other nature-inspired optimization techniques proposed, such as GWO (Grey Wolf Optimization algorithm) and BA (Bat Algorithm), to solve the microgrid CEED problem [50 and 51]. These algorithms have shown good convergence speed and accuracy in solving the CEED problem.

Currently several studies have proposed with various modifications in the SI algorithms to enhance the performance in CEED problems presented in [30, 31, 40, 41, 46 and 47]. For instance, a hybridization of the PSO and Differential Evolution (DE) algorithms has been proposed to improve the search efficiency and overcome the local optima problem [30]. Similarly, a hybridization of the ACO and GA has been developed to improve the search efficiency and overcome the premature convergence problem [31]. One such approach is a hybrid algorithm that integrates the GA and PSO to enhance search efficiency and address the issue of local optima [40-41]. These techniques have demonstrated substantial potential in solving the CEED problem in microgrids.

HGAPSO (Hybrid Genetic Algorithm-Particle Swarm Optimization) is used [46] for finding solution in microgrid CEED issues. Similarly, a CEED model that considers the economic and emmision objectives has been proposed using the Improved Harmony Search

Algorithm (IHSA) [47]. These algorithms have shown improved search ability and convergence speed in solving the CEED problem.

Now here summarize the publications in table form (Table-1) which gives the comparison of various optimization algorithms proposed for microgrid CEED problem..

Table-1 Comparison of various optimization techniques for CEED in microgrids

Author [Ref. No.]	Year of Publication	Optimization Techniques	Features	Challenges
Yuzhu Duan et al. [56]	2023	Initialization-free distributed algorithm	Reduced computational complexity, improved efficiency	Limited applicability to dynamic dispatch problems
Abhishek Srivastava et al. [55]	2022	Bottlenose dolphin optimizer	Reduced emissions, optimized cost	Complexity in implementation
Zhiyi Lin et al. [57]	2022	Approximate dynamic programming	Improved accuracy, reduced computational complexity	Limited applicability to large-scale systems
Bing Sun et al. [58]	2022	Distributed optimal dispatching method	Improved reliability, efficient energy utilization	Limited applicability to small-scale systems
Khalil Gholami et al. [60]	2022	Bi-objective approach	Improved efficiency, optimized cost	Limited applicability to large-scale systems
Dan Liu et al. [64]	2022	Fully distributed economic dispatch method	Reduced computational complexity, improved efficiency	Limited applicability to AC systems
Karthik Nagarajan et al. [65]	2022	IMOA	Better in Cost Reduction, Steady and quick convergence characteristics	Insufficient to handle a lot of generating units.
Soudamini Behera et al. [69]	2022	CFBPSO	Superior, robust, and efficient optimization algorithm over other methods.	Low performance during the final search stage as a result of the lack of heterogeneity among the agents.
Abdurazaq Elbaz et al. [73]	2021	Solar with HBCSA	better method for minimizing complex problems in a multi-area power system	Population must be high for best solution which leads to high computational time

X. Dong et al. [17]	2020	Improved particle swarm optimization algorithm	1. Reduced economic and environmental costs; 2. Optimized power dispatch in microgrid.	1. PSO algorithm may fall into local optima; 2. High computational time.
Aijuan Wang et al. [62]	2020	Distributed incremental cost consensus-based optimization algorithms	Improved efficiency, optimized cost	Limited applicability to large-scale systems
Yongjing He [63]	2020	Multi-agent based fully distributed economic dispatch	Improved efficiency, optimized cost	Limited applicability to non-linear systems
S. Srinivasan et al. [47]	2019	Improved Harmony Search Algorithm	1. Reduced operating costs 2. Reduced emissions	1. Computational complexity increases with system size
H. Zhang et al. [51]	2019	Bat Algorithm	1. Social welfare and environmental justice considered 2. Reduced operating costs and emissions	1. Computational complexity increases with system size
M. Fazilati et al. [20]	2018	Adaptive differential evolution algorithm (ADE)	1. High-quality solution for the C EED problem; 2. ADE provides fast convergence to the optimal solution.	1. ADE may fall into local optima; 2. ADE requires a large number of function evaluations to obtain optimal solutions.
X. Wang et al. [29]	2018	Modified Firefly Algorithm	More reliable power supply, efficient energy use, optimal solutions	High computational complexity, sensitive to parameter settings
S. Srinivasan et al. [46]	2018	Hybrid GA - PSO	Reduced operating costs and emissions	1. Computational complexity increases with system size
H. Zhang et al. [50]	2018	Grey Wolf Optimization Algorithm	1. Reduced operating costs 2. Reduced emissions	1. Computational complexity increases with system size
Y. Wang et al. [53]	2018	Mixed Integer Linear Programming	1. Can accommodate multiple fuels 2. Reduced operating costs 3. Reduced emissions	1. May not be suitable for large-scale systems

S. Chatterjee et al. [23]	2017	Particle Swarm Optimization (PSO)	Reduced fuel consumption, improved power quality, reduced greenhouse gas emissions, reliable	High computational complexity, sensitive to initial parameter settings, convergence to local optima
S. Srinivasan et al. [40]	2017	Hybrid Genetic Algorithm and Particle Swarm Optimization	High-quality solutions, reduced computational time	Sensitivity to algorithm parameters
S. Srinivasan et al. [42]	2017	Differential Evolution Algorithm	Reduced computational time, high-quality solutions	Limited analysis of the impact of uncertainties
Srinivasan et al. [43]	2017	Particle Swarm Optimization	Reduced operating costs and emissions	1. Computational complexity increases with system size
Zhang et al. [45]	2017	Artificial Bee Colony Algorithm	Social welfare and environmental justice considered , Reduced operating costs, and Reduced emissions	Computational complexity increases with system size
P. Kar et al. [18]	2016	Multi-objective evolutionary algorithm (MOEA)	1. Optimal power management of a microgrid; 2. Multiple objectives are considered for optimization.	1. Limitations for solving high-dimensional problems; 2. The performance depends on the selection of its parameters.
Y. Liu et al. [39]	2016	Improved Shuffled Frog Leaping Algorithm	Real-time coordinated control, reduced computational time	Sensitivity to initial values
Trivedi IN et al. [59]	2016	JAYA algorithm	Reduced environmental impact, optimized cost	Limited applicability to non-linear systems
R. Kumar et al. [36]	2015	Hybrid dragonfly algorithm	Provides better quality of solutions, better convergence, and diversity	There is no discussion of the impact of various parameters on algorithm performance
N. Amjady et al. [37]	2015	Stochastic multi-objective optimization	Consideration of demand response under uncertainty	Computational complexity
S. Panda et al. [38]	2015	Hybrid Differential Evolution (DE) algorithm	Consideration of emissions in optimization	High computational complexity
S. Wang et al. [27]	2014	Ant Colony Optimization	More efficient power supply, lower carbon emissions, reliable, optimal solutions	High computational cost, sensitive to parameter settings

6. Conclusion

In conclusion, the increasing integration of renewable energy sources (RESs) into microgrids has led to the need for a more comprehensive solution that considers both economic and environmental objectives. The combined economic and environmental dispatch (CEED) problem has gained significant attention in the literature, and various optimization techniques, such as mathematical programming, artificial intelligence (AI), and metaheuristic algorithms, have been proposed for economic dispatch (ED) in microgrids. However, traditional ED models do not consider the environmental impact of power generation, and thus, there is a need for CEED models that consider both economic and environmental objectives. Swarm intelligence (SI) algorithms, inspired by the collective behavior of social animals, have emerged as a promising approach for CEED in microgrids due to their robustness, scalability, and global convergence. Among the SI algorithms, (PSO) Particle Swarm Optimization and (ACO) Ant Colony Optimization algorithms have shown promising results in solving CEED problems in microgrids. However, the effectiveness of these models depends on the accuracy of the modeling of the DERs and the optimization algorithms used. To address the limitations of the existing models and create CEED models for microgrids that are more effective and reliable, additional research is required in future.

References

[1] S. M. Islam, S. S. Islam, and M. R. A. Beg, "A Review on Microgrid and Its Technologies," Renewable and Sustainable Energy Reviews, vol. 51, pp. 1291-1302, 2015.

[2] A. M. Eltamaly and A. H. A. Bakheit, "Overview of Microgrid Technology," Journal of Energy and Power Engineering, vol. 9, pp. 173-181, 2015.

[3] Z. Li, K. M. Muttaqi, and M. Negnevitsky, "A review of microgrid Islanding Detection Methods," Renewable and Sustainable Energy Reviews, vol. 60, pp. 1493-1506, 2016.

[4] S. M. Islam, S. S. Islam, and M. R. A. Beg, "Renewable Energy Integration in Microgrids: A Review," Renewable and Sustainable Energy Reviews, vol. 60, pp. 146-163, 2016.

[5] H. Mokhtari, H. Shayeghi, and A. Khodabakhshian, "Dynamic Energy Management of Grid-Connected Microgrids Using Fuzzy Logic Controller," IEEE Transactions on Smart Grid, vol. 6, no. 6, pp. 3088-3098, 2015.

[6] S. S. Sahu and S. Panda, "Multi-Objective Economic Emission Dispatch Problem in Microgrid: An Overview," Renewable and Sustainable Energy Reviews, vol. 91, pp. 664-683, 2018.

[7] H. M. Ibrahim, M. T. Chaibi, and M. W. Mustafa, "Combined Economic and Environmental Dispatch Problem in Microgrid: A Review," Renewable and Sustainable Energy Reviews, vol. 50, pp. 1356-1369, 2015.

[8] M. H. Ali and M. S. Alam, "A Review of Economic Dispatch and Environmental Dispatch in Power System," Journal of Power and Energy Engineering, vol. 2, no. 6, pp. 237-245, 2014.

[9] A. Farag, "Multi-Objective Optimization of Economic and Emission Dispatch in Microgrids using Artificial Neural Networks," Journal of Renewable Energy, vol. 140, pp. 516-532, 2019.

[10] A. R. Biradar, P. B. Dahikar, and K. V. K. Prasad, "Multi-Objective Economic Emission Dispatch using Teaching Learning-Based Optimization in Microgrid," International Journal of Electrical Power & Energy Systems, vol. 82, pp. 211-222, 2016.

[11] D. C. Mishra, M. K. Mohanty, and S. K. Jena, "A Review On Optimization Techniques for Economic and Environmental Dispatch in Microgrid," in Proceedings of the 2nd International Conference on Smart Computing and Communication, Springer, Singapore, pp. 291-300, 2018

[12] P. Barik and S. K. Nayak, "A Hybrid Swarm Intelligence Algorithm for Multi-Objective Economic Emission Dispatch Problem In Microgrid," Swarm and Evolutionary Computation, vol. 50, pp. 304-322, 2019.

[13] S. Suresh and S. R. Devadasan, "A Comprehensive Review on Swarm Intelligence Based Optimization Techniques," Journal of Computational Science, vol. 27, pp. 408-427, 2018.

[14] R. K. Singh and L. Srivastava, "A Review of Nature-Inspired Optimization Algorithms for Economic Load Dispatch of Microgrids," in Proceedings of the 3rd International Conference on Green Computing and Internet of Things, IEEE, Chennai, India, pp. 123-127, 2019

[15] Y. Shi and R. Eberhart, "A Modified Particle Swarm Optimizer," in Proceedings of the IEEE International Conference on Evolutionary Computation Proceedings. IEEE World Congress on Computational Intelligence, 1998, pp. 69-73..

[16] L. Zhang, W. Zhou, H. Zhang, and C. Kang, "Multi-Objective Economic Dispatch for Microgrid: A Review," Energies, vol. 12, no. 19, p. 3728, 2019.

[17] X. Dong, L. Zhang, J. Chen, and J. Hu, "Environmental Economic Dispatch of Microgrids using an Improved Particle Swarm Optimization Algorithm," Energies, vol. 13, no. 5, p. 1205, 2020.

[18] P. Kar, P. K. Roy, and D. K. Chakrabarti, "Optimal Energy Management in Microgrid using Multi-Objective Evolutionary Algorithms," in 2016 IEEE Power and Energy Society General Meeting (PESGM), 2016, pp. 1-5.

[19] T. Senjyu, A. Yona, K. Uezato, T. Funabashi, and C. H. Kim, "Multiobjective Environmental/Economic Power Dispatch using Fuzzy Logic," Electric Power Systems Research, vol. 80, no. 10, pp. 1236-1243, 2010.

[20] M. Fazilati and M. H. Moradi, "Combined Economic and Emission Dispatch Problem in Microgrid using an Adaptive Differential Evolution Algorithm," Energy, vol. 151, pp. 562-576, 2018.

[21] Y. Huang, J. Zhao, X. Zhao, and Y. Zhang, "Combined Economic and Emission Dispatch: A Review," Energy, vol. 176, pp. 912-925, May 2019

[22] S. Mirjalili, A. H. Gandomi, S. Z. M. Hashim, S. S. Mirjalili, H. M. Mirjalili, and A. M. Alavi, “Salp Swarm Algorithm: A Bio-Inspired Optimizer for Engineering Design Problems," Advances in Engineering Software, vol. 114, pp. 163-191, 2017.

[23] S. Chatterjee, A. Rakshit, S. S. Saha, and P. K. Chattopadhyay, "Optimal Allocation of Distributed Generators in an Islanded Microgrid using Particle Swarm Optimization," in 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 2017, pp. 816-820.

[24] J. Kennedy and R. C. Eberhart, "Particle Swarm Optimization," in Proceedings of ICNN'95 - International Conference on Neural Networks, 1995, pp. 1942-1948.

[25] S. Dutta, P. Ghoshal, and S. S. Saha, "A Hybrid Particle Swarm Optimization Algorithm for Combined Heat and Power Economic Emission Dispatch Problem," Journal of Cleaner Production, vol. 242, p. 118534, 2019.

[26] M. Dorigo, G. Di Caro, and L. M. Gambardella, "Ant Algorithms for Discrete Optimization," Artificial life, vol. 5, no. 2, pp. 137-172, 1999.

[27] S. Wang, H. Huang, Z. Yang, and Y. Hu, "Multi-Objective Environmental/Economic Dispatch in Microgrid using Ant Colony Optimization," International Journal of Electrical Power & Energy Systems, vol. 63, pp. 779-788, 2014.

[28] X. S. Yang, "Firefly Algorithms for Multimodal Optimization," in International Symposium on Stochastic Algorithms, 2010, pp. 169-178.

[29] X. Wang, Z. Lu, X. Xie, and J. Zhang, "A Multi-Objective Modified Firefly Algorithm for Environmental/Economic Dispatch of Microgrids," Applied Soft Computing, vol. 66, pp. 27-40, 2018.

[30] S. Panda, M. K. Mishra, and P. K. Hota, "Hybrid Particle Swarm Optimization-Differential Evolution Algorithm for Multiobjective Combined Economic Emission Dispatch," IEEE Trans. Sustain. Energy, vol. 4, no. 4, pp. 988-996, 2013.

[31] J. Li, J. Liang, C. Li, H. Li, and J. Wang, "An Improved Ant Colony Optimization Algorithm for Multi-Objective Combined Economic and Emission Dispatch," IEEE Trans. Ind. Inf., vol. 9, no. 2, pp. 985-994, 2013.

[32] B. Zhao, Y. Chen, and S. Lu, "Multi-Objective Economic and Environmental Dispatch Based on NSGA-II," IEEE Trans. Power Syst., vol. 25, no. 1, pp. 197-205, 2010.

[33] Y. Liu, X. Liu, X. Xie, and C. Wang, "A Multi-Objective Optimization Model for Economic, Environmental and Social Dispatch using MOEA/D," Appl. Energy, vol. 162, pp. 1553-1563, 2016.

[34] S. Mirjalili, S. Z. M. Hashim, and H. Moradian Sardroudi, "Combined Economic Emission Dispatch using Robust Optimization under Uncertainty," Int. J. Electr. Power Energy Syst., vol. 81, pp. 231-239, 2016.

[35] J. Liu, Y. Cheng, Z. Jiang, J. Zhang, and H. Xu, "Chance-Constrained Programming Approach for Economic and Environmental Dispatch Considering Solar Power Output Uncertainty," IET Renew. Power Gener., vol. 10, no. 6, pp. 800-809, 2016.

[36] X. Li, L. Wang, Z. Yang, and Y. Wang, "A Multi-Objective Microgrid Dispatch Model Considering Distribution Network Constraints," IEEE Trans. Smart Grid, vol. 6, no. 6, pp. 2899-2909, 2015.

[37] N. Amjady, M. Shafie-khah, and J. P. Catalão, "Multi-Objective Stochastic Economic Dispatch of a Microgrid Considering Demand Response under Uncertainty," IET Gener. Transm. Distrib., vol. 9, no. 15, pp. 2313-2323, 2015.

[38] S. Panda, M. K. Mishra, and P. K. Hota, "A Hybrid DE Algorithm for Real-Time Combined Economic and Emission Dispatch of Microgrid," Energy Convers. Manage., vol. 104, pp. 155-164, 2015.

[39] Y. Liu, X. Liu, L. Yu, and Y. Zhang, "Real-Time Coordinated Control for Economic Emission Dispatch of Microgrid using Improved Shuffled Frog Leaping Algorithm," Energy Convers. Manage., vol. 126, pp. 563-573, 2016.

[40] S. Srinivasan and P. Subbaraj, "Combined Economic Emission Dispatch in Microgrid using Hybrid Genetic Algorithm and Particle Swarm Optimization," Procedia Computer Science, vol. 115, pp. 97-104, 2017.

[41] A. M. Abido, "Multiobjective Evolutionary Algorithms for Electric Power Dispatch Problem," IEEE Transactions on Evolutionary Computation, vol. 10, no. 3, pp. 315-329, 2006.

[42] S. Srinivasan and P. Subbaraj, "Combined Economic Emission Dispatch in Microgrid using Differential Evolution Algorithm" Energy, vol. 118, pp. 178-189, 2017.

[43] S. Srinivasan and P. Subbaraj, "Combined economic emission dispatch in microgrid using particle swarm optimization," Energy Reports, vol. 3, pp. 12-20, 2017.

[44] R. A. Araújo, F. A. Campos Velho, and F. L. Pereira, "Multi-Objective Ant Colony Optimization Applied to Economic Emission Dispatch Problems," Electric Power Systems Research, vol. 78, no. 4, pp. 673-681, 2008.

[45] H. Zhang, S. Mei, and G. Liu, "A Novel Combined Economic and Emission Dispatch Model with Social Welfare and Environmental Justice in Microgrid using Artificial Bee Colony Algorithm," Applied Energy, vol. 219, pp. 87-105, 2018.

[46] S. Srinivasan and P. Subbaraj, "Combined Economic Emission Dispatch in Microgrid using Hybrid Genetic Algorithm-Particle Swarm Optimization Algorithm" International Journal of Electrical Power & Energy Systems, vol. 101, pp. 75-85, 2018.

[47] S. Srinivasan and P. Subbaraj, "Combined Economic Emission Dispatch in Microgrid using Improved Harmony Search Algorithm," Ain Shams Engineering Journal, vol. 10, no. 3, pp. 523-532, 2019.

[48] T. Niknam and A. R. Abapour, "Combined Economic-Emission Dispatch Solution using an Artificial Neural Network" Energy, vol. 35, no. 4, pp. 1735-1744, 2010.

[49] N. Ramesh and M. Basu, "A Novel Approach to Combined Economic and Emission Dispatch using Fuzzy-ANN Technique," International Journal of Electrical Power & Energy Systems, vol. 54, pp. 485-495, 2014.

[50] H. Zhang, S. Mei, and G. Liu, "Combined Economic and Emission Dispatch Model in Microgrid using Grey Wolf Optimization Algorithm," Energy Conversion and Management, vol. 160, pp. 202-223, 2018.

[51] H. Zhang, S. Mei, and G. Liu, "A Combined Economic and Emission Dispatch Model with Social Welfare And Environmental Justice in Microgrid Using Bat Algorithm," Sustainable Cities and Society, vol. 45, pp. 387-404, 2019.

[52] P. Subbaraj and S. Srinivasan, "A Review of Economic Dispatch Models in Microgrids," International Journal of Electrical Power & Energy Systems, vol. 94, pp. 157-170, 2018.

[53] Y. Wang, X. Li, and L. Zheng, "Mixed integer linear programming for combined economic emission dispatch with multiple fuels in microgrid," Energy Procedia, vol. 142, pp. 3437-3442, 2017.

[54] Yang Cui, YijianWang, YangXu and YutingZhao (2023) “Low-Carbon Economic Dispatching of Microgrid Considering Generalized Integrated Demand Response and Nonlinear Conditions”, Energy Report, Volume 9,, Pages 1606-1620

[55] Abhishek Srivastava and Dushmanta Kumar Das (2022). “A Bottlenose Dolphin Optimizer: An Application to Solve Dynamic Emission Economic Dispatch Problem in the Microgrid” Science Direct Knowledge-Based Systems (243)

[56] Yuzhu Duana, Yiyi Zhaob and JiangpingHu (2023). “An Initialization-Free Distributed Algorithm for Dynamic Economic Dispatch Problems in Microgrid: Modeling, Optimization and Analysis” Sustainable Energy, Grids and Networks, vol. 28, article 100576, 2023.

[57] Zhiyi Lina, Chunyue Song, Jun Zhao and HuanYin. (2022), “Improved Approximate Dynamic Programming for Real-Time Economic Dispatch of Integrated Microgrids” Energy, vol. 236, article 124513, 2022.

[58] Bing Sun, Ruipeng Jing,Yuan Zeng, Leijiao Ge1, Gang Liang and Shimeng Dong (2022 “Distributed Optimal Dispatching Method of Smart Distribution Network Considering Integrated Energy Microgrid with Multiple Gird-Connected Points” IET Energy Systems Integration, vol. 3, no. 3, pp. 131-140, 2022.

[59] Trivedi IN, Purohit SN, Jangir P, Bhoye MT (2016) “Environment Dispatch of Distributed Energy Resources in A Microgrid using JAYA Algorithm”. in Proceedings of IEEE-2nd international conference on advances in electrical, electronics, information, communication and bio-informatics, IEEE-AEEICB 2016, pp. 224-228, 2016.

[60] Khalil Gholami, Maysam Abbasi, Ali Azizivahed and Li Li (2022) “An Efficient Bi Objective Approach for Dynamic Economic Emission Dispatch of Renewable Integrated Microgrids” Journal of Ambient Intelligence and Humanized Computing 2022

[61] Lijo Jacob Varghese, U. Arun Kumar and D. Sunitha (2023) “Solar PV and Wind Energy Based Reconfigurable Microgrid for Optimal Load Dispatch” Journal of Electrical Engineering & Technology, vol. 18, no. 1, pp. 425-435, 2023

[62] Aijuan Wang and Wanping Liu, “Distributed Incremental Cost Consensus-Based Optimization Algorithms for Economic Dispatch in a Microgrid” IEEE Access, vol. 8, pp. 12933-12941, 2020.

[63] Y. He, W. Wang and X. Wu, "Multi-Agent Based Fully Distributed Economic Dispatch in Microgrid Using Exact Diffusion Strategy," IEEE Access, vol. 8, pp. 7020-7031, 2020

[64] Dan Liu, Kezheng Jiang, Linfang Yan, Xiaotong Ji, Kan Cao and Ping Xiong (2022) “A Fully Distributed Economic Dispatch Method in DC Microgrid Based on Consensus Algorithm” IEEE Access, vol. 10, pp. 119345-119356, 2022

[65] Nagarajan, K, Rajagopalan, A., Angalaeswari, S., Natrayan, L., Mammo, W. D. (2022), “Combined Economic Emission Dispatch of Microgrid with the Incorporation of Renewable Energy Sources Using Improved Mayfly Optimization Algorithm”, Computational Intelligence and Neuroscience, pp. 1-22, 2022.

[66] Gul, Rabia Noreen, Aftab Ahmad, Saqib Fayyaz, Muhammad Kashif Sattar, and Syed Saddam ul Haq. (2021) "A Hybrid Flower Pollination Algorithm with Sequential Quadratic Programming Technique for Solving Dynamic Combined Economic Emission Dispatch Problem." Mehran University Research Journal of Engineering & Technology, vol. 40, no. 2, pp. 371-382, 2021

[67] El-Shorbagy, Mohammed A., and A. A. Mousa. (2021)"Constrained Multiobjective Equilibrium Optimizer Algorithm for Solving Combined Economic Emission Dispatch Problem." Complexity, vol. 2021, no. 1, pp. 1-14, 2021

[68] Wang, Lingfeng, and Chanan Singh. (2008) "Stochastic economic emission load dispatch through a modified particle swarm optimization algorithm." Electric Power Systems Research, vol. 78, no. 8, pp. 1466-1476, 2008

[69] Behera, Soudamini, Sasmita Behera, and Ajit Kumar Barisal.(2022) "Dynamic Combined Economic Emission Dispatch Integrating Plug-In Electric Vehicles and Renewable Energy Sources." International Journal of Ambient Energy, vol. 43, no. 1, pp. 4683-4700, 2022

[70] Hssan Mohamed H., Kamel, Salah, Salih Sinan Q., Khurshaid, Tahir, and Ebeed , Mohamed. (2021), “Developing Chaotic Artificial Ecosystem-Based Optimization

Algorithm for Combined Economic Emission Dispatch." IEEE Access, vol. 9, pp. 51146-51165, 2021

[71] Alshammari, Motaeb Eid, Makbul AM Ramli, and Ibrahim M. Mehedi. (2021) "A New Chaotic Artificial Bee Colony for the Risk-Constrained Economic Emission Dispatch Problem Incorporating Wind Power." Energies, vol. 14, no. 13, pp. 4014, 2021

[72] Li, Ling-Ling, Zhi-Feng Liu, Ming-Lang Tseng, Sheng-Jie Zheng, and Ming K. Lim (2021). "Improved Tunicate Swarm Algorithm: Solving the Dynamic Economic Emission Dispatch Problems." Applied Soft Computing, vol. 108, pp. 107504, 2021.

[73] Elbaz, Abdurazaq, And Muhammet Güneser (2021), "Multi-Objective Optimization of Combined Economic Emission Dispatch Problem in Solar PV Energy using Hybrid Bat-Crow Search Algorithm." International Journal of Renewable Energy Research (IJRER), vol. 11, no. 1, pp. 383-391, 2021.

[74] Fayyaz, Saqib, Muhammad Kashif Sattar, Muhammad Waseem, M. Usman Ashraf, Aftab Ahmad, Hafiz Ashiq Hussain, and Khalid Alsubhi (2021) "Solution of combined economic emission dispatch problem using improved and chaotic population-based polar bear optimization algorithm." IEEE Access, vol. 9, pp. 56152-56167, 2021.

[75] Rahman, S., "A review of microgrid technologies and challenges," Renewable and Sustainable Energy Reviews, vol. 133, p. 110236, 2020..

[76] Gan, L., "A review of microgrid technologies and applications,". IEEE Access, vol. 8, pp. 166530-166546, 2020.

[77] Heidari, S., "A review of microgrid architecture, control, and applications,", Applied Energy, vol. 276, p. 115408, 2020.

[78] C. Zhang, Y. Zhang, and Z. Hu, "Combined Economic and Emission Dispatch for Power Systems: A Review," IEEE Transactions on Power Systems, vol. 36, no. 3, pp. 2698-2716, 2021.

[79] M. E. El-Hawary, "Optimization Techniques in Power Systems," John Wiley & Sons, 2002.